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A COMPARISON OF LYSIMETER-DERIVED
POTENTIAL EVAPOTRANSPIRATION
WITH COMPUTED VALUES

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NORTH APPALACHIAN EXPERIMENTAL WATERSHED
Coshocton, Ohio 43812

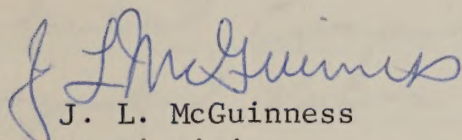
December 10, 1970

Subject: Draft of Report "A Comparison of Lysimeter-Derived
Potential Evapotranspiration with Computed Values

To: R. M. Pasley, Acting Head
Central Technical Unit
Soil Conservation Service
269 Federal Center Building
Hyattsville, Maryland 20782

Thank you for forwarding a copy of the subject report to Jerry
Andrews.

Another copy is attached for the use of your office. As I
told Jerry, we would appreciate receiving any comments,
suggestions, or criticisms you might have on this report.
We will be submitting a revised draft for publication in
mid-January and would appreciate hearing from you by then.


J. L. McGuinness
Statistician

Enclosure

A COMPARISON OF LYSIMETER-DERIVED POTENTIAL
EVAPOTRANSPIRATION WITH COMPUTED VALUES

JANUARY 1971 (ARS 41-)

Agricultural Research Service

UNITED STATES DEPARTMENT OF AGRICULTURE

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A COMPARISON OF LYSIMETER-DERIVED POTENTIAL EVAPOTRANSPIRATION WITH COMPUTED VALUES^{1/}

J. L. McGuinness and Erich F. Bordne^{2/}

INTRODUCTION

Many aspects of water resources planning in humid areas are not as critical as in more arid regions. Estimates of water use, for instance, can be much less precise in humid regions where available water supplies are plentiful and some excesses can be tolerated. This situation is reflected in the fact that much of the current research on evapotranspiration is being done in sub-humid and arid regions.

Pressures on the currently adequate water resources of the more humid areas are increasing, however. The demands of an increasing population, rising use of water by both agriculture and industry, and failure to deal forcefully with our water pollution problems all tend to take us nearer the point where supplies will become marginal. Water supply development in headwater areas already involves the expenditure of hundreds of millions

^{1/}

Contribution from the North Appalachian Experimental Watershed, Corn Belt Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Coshocton, Ohio (in cooperation with the Ohio Agricultural Research and Development Center, Wooster, Ohio) and the Department of Geography, Kent State University, Kent, Ohio.

^{2/}

Research Statistician, USDA, and Professor, Kent State University, respectively.

of dollars annually. Now is the time for building up the body of knowledge which will be necessary to solve the problems which future restrictions in water use will bring.

More immediately, we need to be tooled up to handle today's problems. Techniques for estimating ET effectively would result in better prediction of water supplies to meet current needs and of downstream effects of land practices on water yield. A mathematical model of a humid area watershed may have a system for computing evapotranspiration (ET) which gives values which are too low in one season of the year and too high in another. This discrepancy may not be too serious in the overall performance of the model because the soil moisture storage or some other function may have a compensating error. However, as the errors and biases in estimating precipitation, surface runoff, soil moisture storage, deep percolation, etc. are reduced, it is imperative that the uncertainties in estimating ET also be reduced. Valid prediction of short-term ET amounts is a prerequisite to a complete understanding of the entire hydrologic system.

Actual ET is generally considered to be a function of (1) the potential evapotranspiration (PET), the demand of the atmosphere for water, (2) the soil moisture supply which governs the ability of the plants to transpire at at their maximum rate, and (3) the type of plant cover which affects actual ET through such factors as depth of rooting and canopy roughness among other things.

This report deals with the first of the above functions, the estimation of potential evapotranspiration, PET. Determination of PET is usually the

first step in the estimation of actual evapotranspiration. Several methods have been proposed for estimating PET from climatic measurements -- methods ranging from purely empirical to others with a basis in the physics of the evaporation phenomena. Most of the estimating methods were developed in response to arid land needs and their application in humid areas is somewhat questionable. It is the purpose of this report to compare data obtained through the various estimating methods with those from a lysimeter-derived 'standard' PET curve as an aid to the selection of appropriate estimating methods for humid areas.

Many studies have been made which checked the reliability of computed PET against values measured from open pan evaporation or lysimeters. Almost all of these have utilized relatively short term data, usually less than a year or so. One exception is a study by Smith (S-3) where a 26-year pan evaporation record was used. Data from a 15-year period of record were used in the current study.

The time periods for which PET estimates have been made vary widely. VanBavel (VI) gives a formula for obtaining instantaneous PET rates and calculates PET for periods as short as one hour. On the other hand, Smith (S-3) calculates PET for seasons and entire years in his study. In practical engineering applications, the period of interest usually ranges from one day to one month. The comparisons made in the current study were for these two periods.

In addition to comparing PET estimates with a lysimeter-derived 'standard' curve, another purpose of this report is to incorporate in one

place the various computational techniques required by the various estimating schemes. Some of the estimating methods are arithmetically complex and a 'cook book' approach to their solution should be helpful.

Finally, all the basic data used are tabulated in Appendix B. Thus the reader who wants to test a method not included in this report has all the data available to do so.

DERIVATION OF STANDARD PET CURVE

Much of the research work in evapotranspiration has utilized alfalfa as the experimental crop. Data are available from a deep-rooted grass-legume covered weighing lysimeter at the North Appalachian Experimental Watershed near Coshocton, Ohio for the period 1948-65 less the years 1956, 1957, and 1964 when the cover was being renewed. Thus, 15 years of data were available for this study.

Daily ET from the period of record from 1948 to 1965 were examined by Mustonen and McGuinness (M3) and a listing of measured daily ET values was given in their report. These data form the basis for deriving a series of daily ET values which would have occurred had PET conditions existed. On the average, daily values of ET from the weighing lysimeter growing deep-rooted grass at Coshocton must be less than daily values of PET because (1) the grass is cut for hay which makes for less than a full green cover until some leaf regrowth has taken place, and (2) soil moisture is limiting in almost every year.

First it was necessary to remove the effect of hay cut from the data. Mustonen and McGuinness (M3) found that after haycut, ET fell to about half of normal and then gradually increased until it again reached normal in about 30 days. To correct for this effect, at least 15 days of data were discarded after every hay cut. The succeeding 15 days of data were scanned and subjectively eliminated if their ET-values were still increasing with time. The values remaining after this step should then be representative of PET from a full cover condition, providing soil

moisture supply is not limiting.

Next, the values were corrected for the effect of limiting soil moisture. The equation developed by Mustonen and McGuinness (M3) predicted daily ET during the growing season as

$$ET = 0.7 \text{ PET } SM^{0.25}$$

where ET is daily evapotranspiration, PET is lake evaporation as computed by the U.S. Weather Bureau formula (K1), and SM is the soil moisture in the top 40 inches of the lysimeter soil profile. All units in the equation are water depths in inches. Daily values of both PET and SM as defined above were given by Mustonen and McGuinness (M3).

For each growing season day when SM is below field capacity, ET can be computed from the above equation using first, actual SM and then repeating the computation using field capacity SM. The difference between these two values is an estimate of the additional amount of ET which would have occurred had soil moisture not been limiting. These differences, therefore, were added to the measured ET values to produce a series which should closely represent potential evapotranspiration for deep-rooted vegetation at Coshocton.

Daily values derived as described above were then averaged for each day over the 15 year period of record. The resulting 366 averages are shown by the points plotted on figure 1. The curve drawn through the scatter of points is a 5-term harmonic curve fitted to the daily averages. This smooth curve is taken to be as close a representation of the seasonal PET pattern as can be obtained from the Coshocton lysimeters. Daily values are tabulated in Appendix table B 30.

POTENTIAL EVAPOTRANSPIRATION (INCHES)

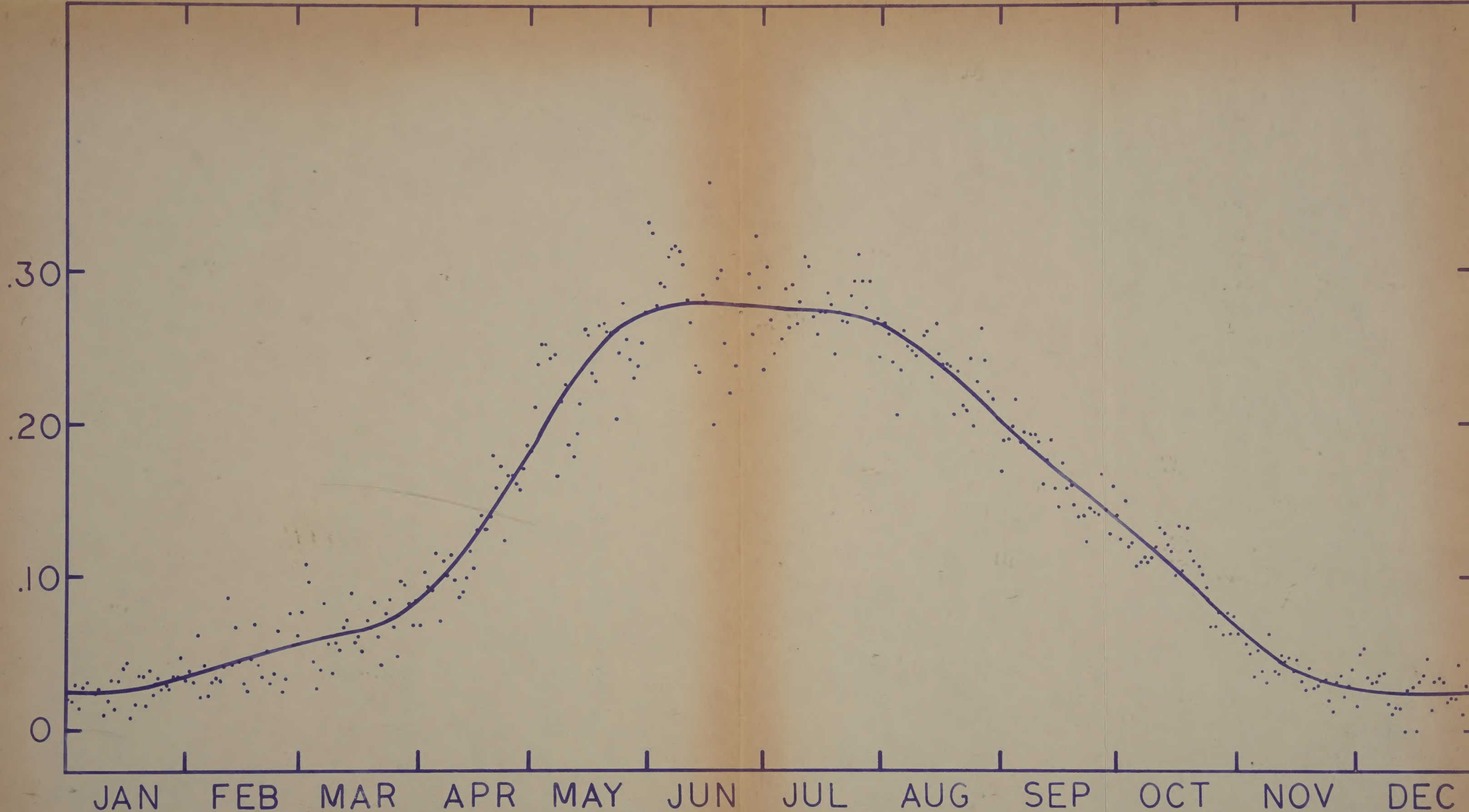


Fig. 1. -- Average daily potential evapotranspiration (PET) as measured by a lysimeter growing deep-rooted grass, 1948-1965 less 1956, 1957, and 1964.

Observed ET values have been adjusted to remove the effect of haycut and of soil moisture below field capacity in the top 40 inches of soil.

In evaluating the Coshocton lysimeters, Mustonen and McGuinness (M3) concluded that the lysimeter ET values obtained were too high as compared with ET values from surrounding grassed fields but that there was no seasonal bias in the difference. Thus, the curve of figure 1, while it has the correct shape, may be too high by a fixed amount per day throughout the year. The 'standard' PET curve of fig. 1 will be referred to in quotation marks throughout this report as a reminder of this possible difference.

COMPUTED PET CURVES

Numerous formulae and methods for computing PET have been proposed over the years. All of these methods use climatic information in their development. Most of the empirical methods require the input of only one or two commonly available parameters such as mean daily air temperature or air temperature plus radiation. The success of these empirical methods depends on the correlation of PET with the input parameters. There is always the danger that empirical methods may not operate too satisfactorily outside the climatic regime in which the original correlations were developed.

One newer method of estimating PET, the combination method, is based on the physics of the evaporation process. The combination method involves the simultaneous solution of the aerodynamic equation and the energy balance equation. Input requirements are more stringent than in most empirical methods, requiring air temperature, humidity, wind, and solar (or net) radiation parameters.

The climatic data required by the various methods were averaged in much the same manner as the data for the "standard" PET curve. Thus, air temperature data from the Coshocton station were averaged over the same period as for the PET data, a harmonic curve was fitted to the data, and the 366 daily values of the fitted curve were used as the air temperature input for the various PET methods. Smoothed input values of mean daily dew point temperature, wind in miles per day, solar radiation in

langleys per day, and computed pan evaporation in inches per day were all determined in this same manner.

It should be emphasized that almost all the normal day-to-day variability has been removed from the climatic input data and from the 'standard' PET curve. The final data sets are the result of first averaging 15 years of data and then fitting a smooth curve through the resulting data points. The input data for the various PET formulas and the 'standard' PET data are taken from these smooth curves. These smoothed input data were then used to compute PET curves by methods advocated by various workers over the years. These methods have been classified by their climatic input requirements and are described briefly below. A detailed description of the computational methods is given in Appendix A.

The methods of computing PET described below and in Appendix A are by no means exhaustive. Many of the more widely used methods are included. However, the basic data used in this study are tabulated in Appendix B so that the reader can apply other techniques should he so desire.

A. Air Temperature Only. Two well-known systems for computing PET from air temperature data only are the Thornthwaite (T1) and the Blaney-Criddle (B1) methods. Both methods have been widely used and are well known. Daily values of crop growth stage for the Blaney-Criddle method were obtained by plotting monthly values on calendar paper, drawing a smooth curve through the points, and reading off daily values from the curve. The Hamon and Papadakis methods also require an input of air temperature although they also utilize a humidity function.

In both cases, the humidity term can be obtained from tabled values using air temperature as the argument. Again, the methods were modified from a monthly basis when necessary.

B. Air Temperature plus Solar Radiation. The methods falling in this category include those of Grassi (G1), Stephens and Stewart (S1), Turc (T2), Jensen and Haise (J1) and Makkink (M2).

C. All Pertinent Climatic Inputs. The method used in this class is that developed by Christiansen (C1). Although empirical, Christiansen's method provides for the inclusion of as many climatic parameters as are available.

D. Combination Methods. The remaining methods, all based on the combination method, include Penman (P1), van Bavel (V1) and the pan and lake evaporation methods of Kohler, Nordenson, and Fox (K1).

For each of the above methods, values of PET were computed for each day of the year. In addition, the input values were averaged for each month and monthly PET was also calculated by the various methods.

The data were also analyzed for an April-October growing season period as well as for the whole year. For some purposes such as irrigation scheduling, only the growing season data are pertinent. Since many hydrologic analyses require data for the entire year, the methods are also compared on this basis.

RESULTS

Daily PET values derived from each of the methods listed in the preceding section were compared with daily values from the lysimeter PET curve (the 'standard' curve). Tabulations of the smoothed climatic data used as input to the computations and the computed PET values for each method are given in Appendix B. Computational details for each method are given in Appendix A.

Graphs of the comparisons of computed PET curves with the 'standard' lysimeter PET curve are given in figures 2-5. The solid line curve on figure 2 is the 'standard' lysimeter curve while the broken lines are daily PET values as computed by the Thornthwaite, Blaney-Criddle, Hamon, and Papadakis methods. These were the methods using air temperature only as input. The other figures ~~in this set are for the other three~~ groups of methods listed previously and in every case the solid curve represents the 'standard' lysimeter data.

In addition to daily values as given in figures 2-5, monthly values of PET were also computed by the various methods. Results of these calculations are given in Table 1 along with the lysimeter - derived values for comparison. The monthly values of Table 1 were computed by using average monthly values of temperature, radiation, etc. as input to the various formulas -- they are not the sums of the daily values in figures 2-5.

The statistical method used to compare the 'standard' curve and the computed curves was the root mean square computed as

$$R. M. S. = (D^2 / N)^{0.5}$$

Table 1.--Monthly values of PET for various methods computed using average monthly values as input.

Method	J	F	M	A	M	J	J	A	S	O	N	D	Total
AIR TEMPERATURE													
Thornthwaite	0.00	0.00	0.31	1.70	3.50	4.69	5.56	4.99	3.46	1.93	0.47	0.00	26.61
Blaney-Criddle	.34	.45	.83	2.35	4.84	6.66	7.74	6.72	4.36	2.34	.79	.37	37.79
Hamon	.43	.54	.97	1.85	3.30	4.40	5.08	4.30	2.73	1.56	.75	.46	26.37
Papadakis	.69	.78	1.18	1.91	2.94	3.43	4.07	3.99	3.16	2.23	1.12	.71	26.21
AIR TEMPERATURE PLUS SOLAR RADIATION													
Grassi	1.68	2.21	3.34	4.60	6.22	6.86	7.09	6.29	4.78	3.32	1.90	1.42	49.71
Stephens-Stewart	.12	.23	.75	1.86	3.37	4.26	4.73	4.14	2.80	1.53	.53	.16	24.48
Turc	.00	.00	.88	2.93	4.78	5.57	5.91	5.27	3.91	2.45	.85	.00	32.55
Jensen-Haise	.03	.18	.98	2.81	5.30	6.81	7.62	6.65	4.45	2.35	.73	.14	38.05
Makkink	.67	.97	1.71	2.78	4.12	4.72	4.96	4.37	3.20	2.03	.96	.57	31.06
AVAILABLE CLIMATIC INFORMATION													
Christiansen	.79	1.14	2.05	3.48	5.21	5.84	6.32	5.71	4.39	3.05	1.52	.80	40.30
COMBINATION METHODS													
Penman	1.26	1.73	2.89	4.12	5.59	6.13	6.59	5.77	4.20	2.97	1.66	1.28	44.24
Van Bavel	2.32	2.99	4.54	5.90	7.21	7.38	7.84	6.92	5.34	4.45	2.93	2.49	60.31
Lake Evaporation	.65	.90	1.67	2.84	4.36	5.06	5.39	4.59	3.15	1.99	.98	.57	32.15
Pan Evaporation	1.09	1.35	2.31	3.74	5.54	6.34	6.97	6.05	4.29	3.01	1.65	1.01	43.35
LYSIMETER DERIVED													
Lysimeter	.67	1.06	1.66	3.13	6.03	6.70	6.83	5.89	4.03	2.55	.98	.61	40.14

POTENTIAL EVAPOTRANSPIRATION (INCHES)

0
.10
.20
.30

JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC

LYSIMETER
BLANEY CRIDDLE
THORNTHWAITE
HAMON
PAPADAKIS

Fig. 2. -- Average daily potential evapotranspiration (PET) as estimated from a lysimeter growing deep-rooted grass and as computed by the Thornthwaite, Blaney-Criddle, Hamon, and Papadakis methods.

POTENTIAL EVAPOTRANSPIRATION (INCHES)

.30
.20
.10
0

JAN

FEB

MAR

APR

MAY

JUN

JUL

AUG

SEP

OCT

NOV

DEC

GRASSI

LYSIMETER

STEPHENS-STEWART

JENSEN-HALSE

TURC

MAKKINK

Fig. 3. -- Average daily potential evapotranspiration (PET) as estimated from a lysimeter growing deep-rooted grass and as computed by the Grassi, Stephens-Stewart, Turc, Jensen-Halse, and Makkink methods.

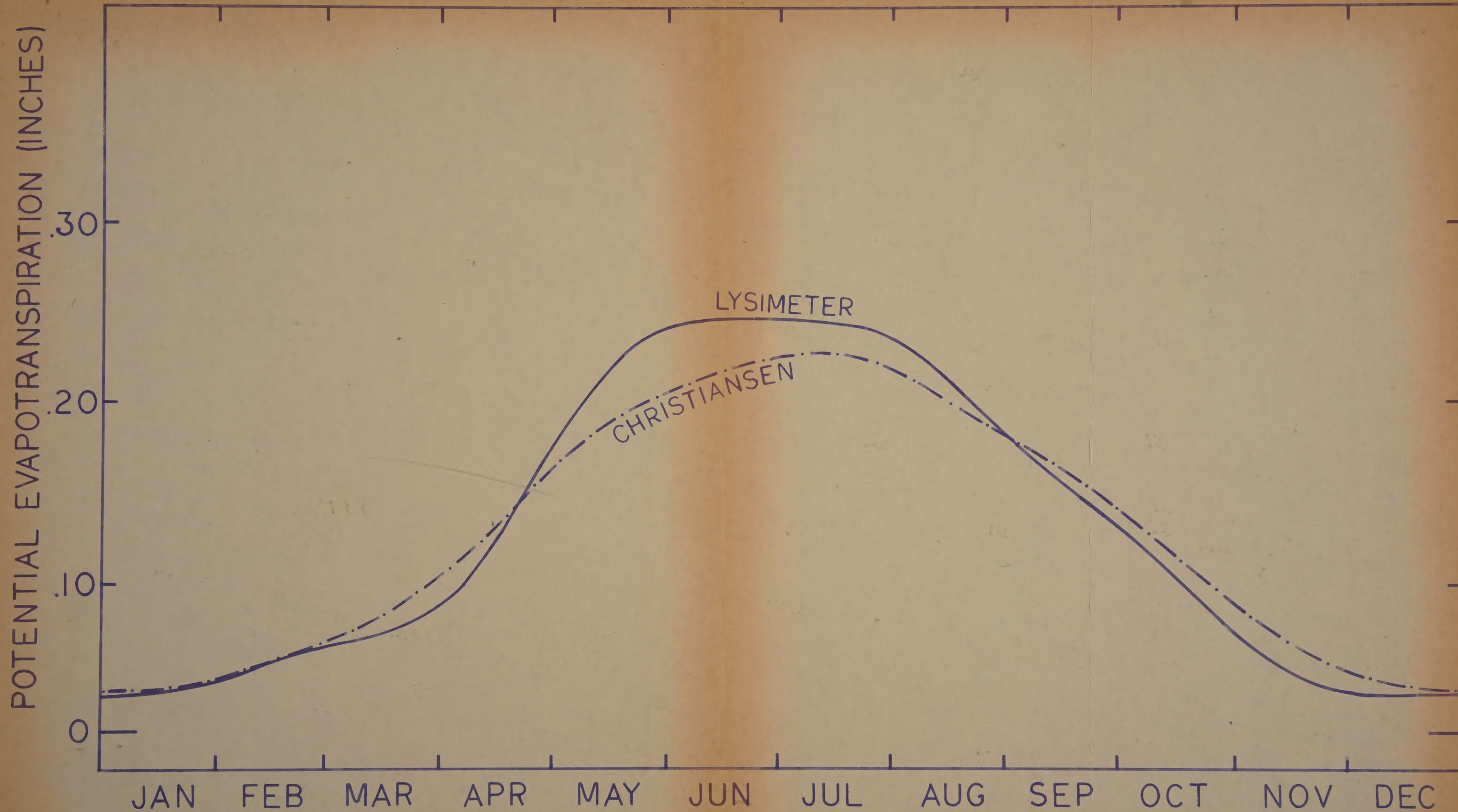


Fig. 4. -- Average daily potential evapotranspiration (PET) as estimated from a lysimeter growing deep-rooted grass and as computed by the Christiansen method.

POTENTIAL EVAPOTRANSPIRATION (INCHES)

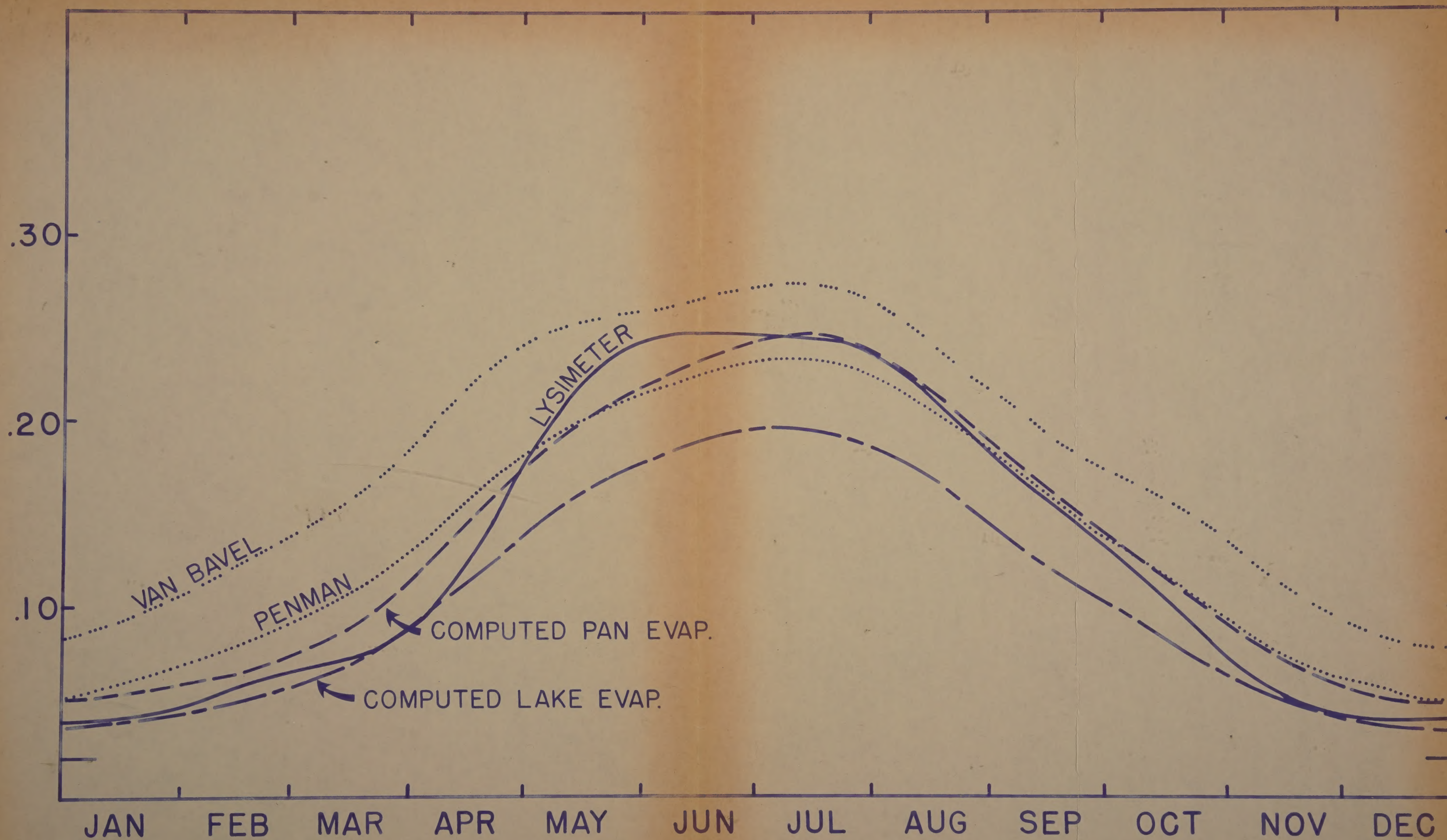
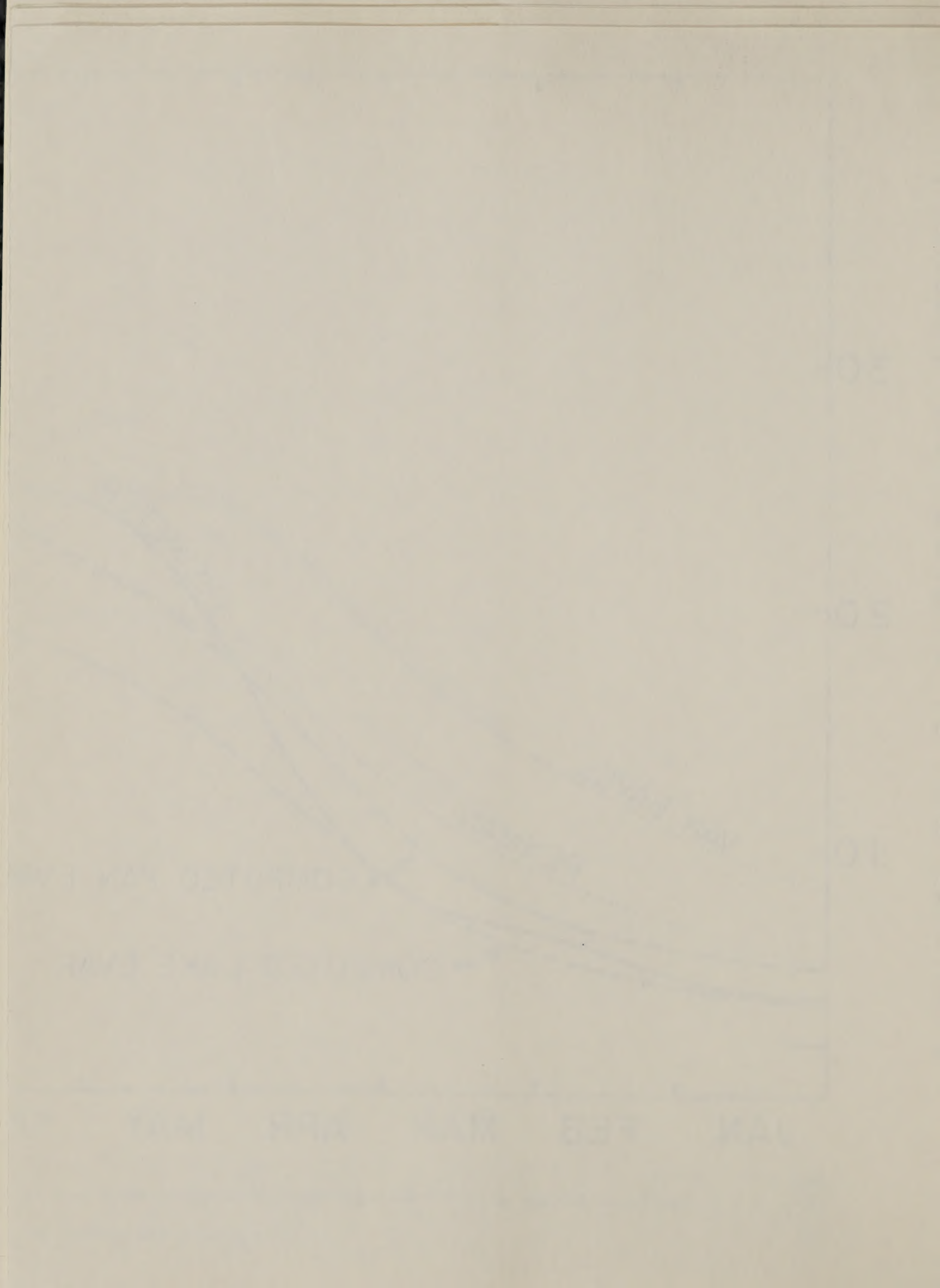


Fig. 5. -- Average daily potential evapotranspiration (PET) as estimated from a lysimeter growing deep-rooted grass and as computed by the Penman, van Bavel, and U. S. Weather Bureau methods.



where D is the sum of the daily differences between values from the 'standard' and computed curves and N is the number of observations. This statistic gives equal weight to absolute differences between the 'standard' and computed curves.

As discussed earlier, the 'standard' lysimeter PET curve values may be too high but the shape of the curve is probably correct. Thus, the fact that the 'standard' curve is higher on the chart than the Thornthwaite curve (figure 2) may be partly due to this cause. In order to compare the shapes of the two curves, the 'standard' curve was shifted by subtracting a constant from each daily value of the 'standard' PET curve to make the area under it equal to the area under the Thornthwaite curve. This procedure makes the mean daily PET equal for the two curves under comparison.

Root mean square values were computed for the comparisons of 'standard' vs. PET values, figures 2-5 as well as for the 'shifted standard' vs. PET values. In the first case, the magnitude of the PET values is taken into account and the R. M. S. statistics are a measure of the goodness-of-fit between the 'standard' and computed curves, figures 2-5. The comparison of 'shifted standard' vs. PET is essentially a comparison of the shapes of the 'standard' vs. computed PET curves where the magnitude has been normalized.

Results of the root mean square comparisons are given in Table 2 for daily values and in Table 3 for monthly values. Both tables give annual totals of the PET values.

Table 2.--Yearly and April-October growing season PET as computed from daily values with root mean squares for unadjusted and adjusted lysimeter values.

Method	Annual Total	Unadj. R.M.S.	Adj. R.M.S.	Seasonal Total	Unadj. R.M.S.	Adj. R.M.S.
AIR TEMPERATURE						
Thornthwaite	26.63	0.04	0.02	25.79	0.05	0.02
Blaney-Criddle	38.11	.02	.02	35.22	.02	.02
Hamon	26.52	.05	.01	23.34	.06	.01
Papadakis	26.30	.06	.02	21.79	.07	.02
AIR TEMPERATURE PLUS SOLAR RADIATION						
Grassi	49.73	.03	.03	39.17	.02	.02
Stephens-Stewart	24.58	.05	.01	22.76	.06	.01
Turc	32.55	.03	.01	30.82	.03	.01
Jensen-Haise	38.24	.02	.02	36.10	.02	.02
Makkink	33.11	.04	.01	26.21	.05	.01
AVAILABLE CLIMATIC INFORMATION						
Christiansen	40.42	.02	.02	34.08	.02	.02
COMBINATION METHODS						
Penman	44.03	.02	.02	35.40	.02	.02
Van Bavel	59.83	.06	.04	45.06	.05	.04
Lake Evaporation	32.18	.03	.01	27.44	.04	.01
Pan Evaporation	43.35	.02	.02	36.02	.01	.01

Table 3.--Yearly and April-October growing season PET as computed from monthly values with root mean squares for unadjusted and adjusted lysimeter values.

Method	Annual Total	Unadj. R.M.S.	Adj. R.M.S.	Seasonal Total	Unadj. R.M.S.	Adj. R.M.S.
AIR TEMPERATURE						
Thornthwaite	26.61	1.28	0.64	25.83	1.49	.57
Blaney-Criddle	37.79	.64	.68	35.01	.73	.73
Hamon	26.37	1.40	.95	23.22	1.80	.38
Papadakis	26.21	1.69	.51	21.73	2.20	.55
AIR TEMPERATURE PLUS SOLAR RADIATION						
Grassi	49.71	.93	.97	39.16	.72	.60
Stephens-Stewart	24.48	1.50	.32	22.69	1.88	.29
Turc	32.55	.75	.47	30.82	.77	.29
Jensen-Haise	38.05	.58	.64	35.99	.54	.52
Makkink	31.06	1.10	.30	26.18	1.44	.26
AVAILABLE CLIMATIC INFORMATION						
Christiansen	40.30	.48	.48	34.00	.56	.49
COMBINATION METHODS						
Penman	44.24	.65	.77	35.37	.51	.51
Van Bavel	60.31	1.80	1.71	45.03	1.55	1.06
Lake Evaporation	32.15	.93	.23	27.38	1.22	.21
Pan Evaporation	43.35	.44	.51	35.94	.39	.40

DISCUSSION

The lysimeter 'standard' curve shown on figure 1 and tabulated in table B30 is partly computed and partly measured. Mustonen and McGuinness (M3) found that the lysimeter over-estimated annual field evapotranspiration. They drew no conclusions on the ability of the lysimeter to assess potential evapotranspiration.

A recent Technical Note of the World Meteorological Organization (G 3) lists the following requirements for reliability of evapotranspirometer measurements which are applicable to the Coshocton lysimeters:

1. Disturbances due to the existence of the evapotranspirometer must be minimal.
2. Evapotranspirometer area must be sufficiently large to give a representative vegetative cover and to minimize disturbances due to walls.
3. Evapotranspirometer depth must permit free growth of plant roots.
4. The width of the annulus formed by the containing and retaining walls plus the gap separating them should be as small as possible.
5. Restricted drainage at the bottom resulting from surface tension at the soil-air interface must be prevented.
6. The temperature below the soil container should be regulated when necessary, to minimize disturbances due to thermal isolation from the soil beneath.
7. Vertical seepage at the walls can be reduced by using shallow corrugated walls and inward projecting flange rings to break the direct flow.

8. The evapotranspirometer should be located at a sufficient distance from the upwind edge of the surrounding area.

9. The surface should be covered with vegetation typical of the surrounding area and the state of plant growth inside and outside the evapotranspirometer must also be similar.

10. It is important that the local soil should be representative of the area under study and that the evapotranspirometer soil correspond closely to that under natural undisturbed conditions.

11. The soil surface inside and outside the evapotranspirometer must be at the same level.

12. Agricultural operations should be carried out at the same time and at the same intensity as in the surrounding field.

13. To avoid wind loading effect, evapotranspirometers should not be weighed in windy conditions.

14. To avoid errors due to rainfall catch, the plants in the evapotranspirometers should be kept vertical, and broken leaves should not extend outside the tank.

With the exception of requirement 4, adequate provisions have been made in installing and operating the Coshocton lysimeters to satisfy the other 13 requirements. The perimeter of the lysimeter was about 16 inches wide during much of the period of record when data for this report were being assembled. This wide border area is one of the reasons for putting the 'standard' curve in quotation marks as a reminder that the values may be too high. The lysimeter perimeter has been about 3 inches wide since 1964.

Detailed descriptions of the Coshocton lysimeters have been published by Harrold and Dreibelbis (H6, H7).

Parmelee (P5) recently made an intensive study of evapotranspiration at the Coshocton lysimeter. Under high soil moisture (PET) conditions, he found that the Bowen ratio method of estimating ET gave almost identical values as those measured with the lysimeter. This lends some confidence to the use of lysimeter values, at least as measured under PET conditions.

The shape of the lysimeter 'standard' PET curve (fig. 1) is a little startling at first glance. The broad crest of the curve covering June and July seems anomolous since the expectation is for a more peaked curve. After all, PET is primarily regulated by solar radiation which means that a peak should occur in late June (table B5). However, the crop during these months is either (a) an old, mature meadow which is almost ready for cutting or (b) the freshly regrown meadow at least 2 weeks after the first cutting has been made. Thus, plant physiology is probably affecting the ET values during this period. It should also be noted that more variation occurs in the data at this time of year than any other (figure 1).

When soil moisture was below field capacity, a correction was added to ET to arrive at a PET value with soil moisture not limiting. The method of computation should not have introduced any bias into the 'standard' curve. A little algebra shows that only the effect of limiting soil moisture was allowed for and that the effect of PET in the correcting equations cancels out. Daily values of average soil moisture are given in Appendix table B4.

The climatic and other input data used in the calculation of the theoretical PET curves were not all collected on site. Of the input factors tabulated in Appendix B, only air temperature and humidity, soil moisture, and lysimeter PET were derived from on-site measurements.

The most important missing on-site data is undoubtedly radiation. The values of solar radiation in table B5 are a mixture of actual measurements at Wooster and values computed from sunshine measurements at Columbus. Both locations are close enough to Coshocton to be representative of Coshocton solar radiation conditions. The fact that 15 years of data were averaged for each day and the daily averages were then fitted with a smooth curve to get the values of table B5 also helps to achieve a realistic pattern of solar radiation values.

Smoothing the climatic data has resulted in input variates which are averages rather than maximums. For instance, the air temperature value of 71.0 used for July 1 (table B1) is the average value expected whereas a maximum average daily temperature for that date might be in the 80's. Therefore, the computed PET curves must also represent average rather than maximum PET conditions. The derivation process for the 'standard' lysimeter curve is such that it too represents average rather than maximum conditions.

Inspection of tables 2 and 3 shows that no one group of methods is particularly outstanding. The Blaney-Criddle, Jensen-Haise, Christianson, Penman, and Pan Evaporation methods all gave annual totals within 10 percent of the 40.14 inches indicated by the 'standard' curve. In each of these five

cases, the root mean square values for both the unadjusted and adjusted curves are low indicating a close fit between the shapes of the 'standard' and theoretical curves. These same PET curves were also within 10 percent of the 35.16 inches indicated by the 'standard' curve for the April-October growing season and again the low root mean square values indicated a close fit of the curve shapes.

The Thornthwaite curve of figure 2 is consistently below the lysimeter 'standard' values. Annual totals were 26.63 and 40.14 inches respectively. This is in contrast to the findings of Smith (S1) who found that Thornthwaite values consistently exceeded pan evaporation on an annual basis in the temperate maritime climate of northern England. Makkink (M2), in the same general geographical area, reported that Thornthwaite values of PET were very similar to measured lysimeter values in the Netherlands.

Note that the Thornthwaite curve on figure 2 shows zero values of PET from December 6 to March 3 when mean daily air temperatures are less than 32°F. The fit to the 'standard' curve is better during the fall months than during the spring. The Thornthwaite method is widely used because of its simplicity and because it is part of a system for computing the water balance (T4).

Pelton, King, and Tanner (P8) found that PET estimates by the Thornthwaite method are not reliable when based on short-term mean temperatures. They reasoned that the failure of the Thornthwaite method over short time periods is due to the fact that short-term mean temperature is not a suitable index of incoming radiation. Stern and Fitzpatrick (S5) also reported that

empirical relationships based on temperature had no practical value as short-term predictors in the dry monsoonal climate of northwestern Australia.

Smith (S3) compared PET values calculated by the Thornthwaite and Penman methods with a 26-year record of measured pan evaporation. Thornthwaite estimates were greater than pan evaporation especially in summer while Penman estimates were lower than pan values especially in the fall. In the current study, the computed pan evaporation curve (figure 5) was higher than the Thornthwaite curve in every season and especially in the first half of the year.

The Blaney-Criddle curve on figure 2 resembles the lysimeter 'standard' curve much more than the other curves requiring temperature only as input. The annual total of 38.11 inches compares favorably with the 40.14 inch total from the lysimeter. The greatest discrepancy between the curves amounts to about 15 percent at the summer peak. The Blaney-Criddle technique is widely used in irrigation agriculture but seems to be well adapted to the humid Eastern environment.

The curve computed by Hamon's (H1) method is based on possible hours of sunshine and the saturated water vapor density at the daily mean temperature. The curve is consistently low in all seasons and especially so in the growing season. A more recent version of the formula (Hamon, H2) was also tried but the results were slightly more at variance with the 'standard' curve than the curve on figure 2 and the results are not presented herein. Jones (J3) found that the Penman method gave larger values than the Thornthwaite and Hamon methods in spring and early summer.

He chose the Hamon method for his study of the variability of ET in Illinois because of its greater simplicity and ease of calculation.

The Papadakis curve shown on figure 2 is derived from the saturated vapor pressure at the daily maximum and mean daily dew point temperatures. The annual total is 26.30 inches compared with 40.14 inches for the 'standard' curve. The Papadakis curve matches the 'standard' curve during winter but is much flatter during the rest of the year.

All of the computed PET curves peak during middle to late July in harmony with the distribution of air temperature (table B1). In contrast, the PET curves of figure 3 all peak earlier in the season more in accord with the distribution of solar radiation.

Figure 3 shows the lysimeter 'standard' curve compared to five methods of computed PET which require a knowledge of solar radiation. The Grassi (G1) formula requires inputs of solar radiation, air temperature and coefficients for type of crop and density of cover. The annual total of 49.73 inches is somewhat above the 40.14 inches for the standard curve. The fit to the 'standard' curve is good around the peak but the Grassi curve overestimates at other times. Grassi (G1) has also devised a method which utilizes measurements of cloud cover when solar radiation measurements are not available.

The Stephens and Stewart (S2) curve shown on figure 3 also utilizes measurements of solar radiation and air temperature to compute PET. The yearly total, 24.58 inches, is lower than the 40.14 inches from the lysimeter. The curve is consistently low and it seems likely that this

method might have performed better had new coefficients been developed which would better reflect the Ohio climate.

Turc (T2) also developed a formula for computing PET using solar radiation and air temperature as inputs. His curve, shown on figure 3, totals 30.88 inches for the year. This method too gives zero estimates of PET for the December 6 to March 2 period when air temperatures are below freezing.

The Jensen and Haise (J2) formula gives values of PET which were designed for irrigated fields in the arid and semi-arid west. The curve shown on figure 3 totals 38.24 inches, very close to the 40.14 inches of the lysimeter. The shape of the Jensen and Haise curve closely resembles that of the lysimeter curve being somewhat higher in the summer season and low at other times.

The final method using solar radiation and air temperature as inputs is the Makkink (R1) formula, figure 3. The annual total is 33.11 inches. The curve matches the "standard" curve during the winter season but is low at other times.

The method developed by Christiansen (C1) and his associates and shown on figure 4 has the advantage of permitting the user to utilize all the climatological information available at a site. The equation is so structured that the prediction is applicable to the mean values of any factors omitted from the prediction equation as well as the actual values of the factors included. The total for the year for the Christiansen curve is 40.42 inches, quite close to the 40.14 inches of the "standard" curve and the fit is good throughout the year.

Figure 5 shows the comparison of various combination methods of computing PET as compared with the 'standard' lysimeter curve. The inputs to the Penman equation (P2, P3) were air temperature, dew point temperature, wind speed, solar radiation, and albedo. The total for the year, 44.03 inches, is close to the 40.14 inches from the lysimeter. The Penman curve underestimates during spring and summer but fits the 'standard' curve closely throughout the year.

The Van Bavel (V1) method of computing PET has the same climatic inputs as the Penman method. The yearly total, 59.76 inches, is considerably higher than the 40.14 inches of the 'standard' curve. The Van Bavel curve has the same general shape as the Penman curve but is displaced about 0.04 inch per day higher.

The lake and pan evaporation curves were computed by the Weather Bureau method (K1). Input values to the formulae are the same as in the Penman method except for albedo. The annual total of 32.18 for lake evaporation is below the 43.35 inches of pan evaporation. The latter figure compares favorably with the 40.14 inches from the lysimeter.

Aslyng (A2) found in Denmark that the Penman method over-estimated PET for the year and the first part of the summer, but was in good agreement with measured values the last half of the year. In the current study, the Penman method underestimated for late spring and summer but was in good agreement for the year.

Papadakis (P1) concluded that the Penman formula should be reduced to saturation deficit, multiplied by a constant thus implying that the radiation

and wind terms should be ignored. He criticizes the Penman method as underestimating ET in the dry climates, overestimating that of spring, underestimating that of autumn, and overestimating that of windy days.

Fitzpatrick and Stern (F1) found that the use of inappropriate constants in the Penman formula is probably a greater source of error when determining PET than instrument deficiencies.

Cruff and Thompson (C3) investigated the Thornthwaite, Weather Bureau, Lowry-Johnson (L3), Hamon, Blaney-Criddle, and Lane (L2) methods of computing PET in arid and subhumid conditions. Only the Weather Bureau method gave estimates of PET that agreed closely with pan evaporation at all sites. However, for practical use, the Blaney-Criddle method was recommended.

Rijtema (R1) compared values of PET from the formulae of Penman, Makkink, Turc, and Haude (H5) with measured values from a pan and from lysimeters in grass. He concluded that it is possible to calculate PET with the formulae of Penman, Makkink, and Turc with the same degree of accuracy as is obtained with lysimeters or evaporation pans.

Stanhill (S4) compared eight methods of computing PET with lysimeter data under arid conditions in Israel. He found that the Penman formula gave the best results for monthly and weekly periods, with the formulas of Thornthwaite, Blaney-Criddle, and Makkink being next best.

Jensen (J4) reviewed empirical methods for estimating PET and concluded that 'those using radiation as the primary variable provide adequate and reliable estimates of evapotranspiration for most engineering purposes when limited meteorological data are available.'

Stephens and Stewart (S2) compared correlation coefficients for measured versus computed monthly pan evaporation for 16 station years in Florida. The highest correlation was for the U.S. Weather Bureau pan evaporation method followed by those of Stephens and Stewart, Blaney-Criddle, Penman, Hamon, and Thornthwaite. For a 30-month comparison with the PET from St. Augustine grass in southern Florida, the methods from high to low correlation were Stephens-Stewart, Penman, pan evaporation (U.S. W. B.), Blaney-Criddle, Hamon, and Thornthwaite. They suggest the Blaney-Criddle method as suitable where data are limited.

Nijtema (R2) points out that many calculation methods lead to an underestimate of PET. He states that this is apparently not too serious in present day irrigation practice since soil fertility is not near optimum and the calculated values of PET are corrected with a factor for irrigation efficiency.

It seems likely that computational methods for estimating PET will be used in agriculture and other endeavors for some time to come. The current trend toward use of the more complex combination methods and away from the simpler empirical methods will probably continue. However, the more demanding input requirements of the combination methods insures that the empirical methods will continue in use into the foreseeable future.

SUMMARY AND CONCLUSIONS

A "standard" potential evapotranspiration curve was derived from measured lysimeter values. Corrections were made for the effects of hay cutting and limiting soil moisture. Thus, the "standard" PET curve represents the ET which could be obtained with non-limiting soil and vegetative conditions.

Fourteen methods of computing PET daily values were segregated into groups depending upon the climatic inputs required. In the temperature only group, the Blaney-Criddle method gave the closest fit to the "standard" curve. The methods of Thornthwaite, Hamon, and Papadakis gave less satisfactory results.

The method of Jensen-Haise was best in the group using temperature plus solar radiation as input. The methods of Grassi, Stephens-Stewart, Turc and Makkink were also included in this group. The Christiansen method was the only entry in the group using all available climatic information and provided a good fit to the "standard" curve.

Under combination methods, the U.S. Weather Bureau pan evaporation and the Penman formulas gave good fits to the "standard" curve. The U.S. Weather Bureau lake evaporation and the Van Bavel methods were also included.

Comparisons were made on both a daily and monthly basis for the entire year and the April-October growing season. The

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The method of Jensen-Haise was best in the group using temperature plus solar radiation as input. The method of Griggs, Stephens-Stewart, Turc and Hargreaves were also included in this group. The Christiansen method was the only entry in the group using all available climatic information and provided a good fit to the "standard"

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goodness-of-fit of the computed to the "standard" curve was evaluated by the root-mean-square procedure.

ACKNOWLEDGEMENTS

The authors are grateful to W. W. Bentz and M. E. Young of ARS for the collection and tabulation of most of the lysimeter data.

J. H. Wilson of the Ohio Agricultural Research and Development Center, Wooster, Ohio, and Grant Vaughan and H. S. Kenny of the U. S. Weather Bureau offices at Akron-Canton and Columbus Airports, respectively, furnished part of the climatic data used in the analyses. Clayton Campbell of the Computer Center at Kent State University programmed the Burroughs 5500 computer. Mrs. C. A. Salrin and Mrs. S. L. Cherry of ARS handled much of the data processing.

This research was supported in part by a grant to one of the authors (E. F. B.) from the Faculty Research Grant, Kent State University.

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APPENDIX A

This Appendix of the report gives computational details for each method of computing potential evapotranspiration discussed in the main body of the report. The formula as given in the original reference is given first. Any changes needed to convert units and to obtain a daily estimate are then made. Finally, a numerical example is given using July 1 data.

The order of presentation of the formulas in this Appendix follows that of the main section of the report.

Thornthwaite Method.

Instructions and tables for calculating PET by this method have been published by Thornthwaite and Mather (TI). Basically, mean monthly air temperatures are used to compute a heat index, I. Daily unadjusted PET is obtained from tables which use daily air temperature and I as the arguments. The final adjusted PET values are obtained after a correction for day length.

When followed explicitly, the published instructions (TI) produced a computed curve resembling a series of steps up and down the graph. The tabled values of unadjusted PET were given to two decimal places and lacked sensitivity when used with the smoothed air temperature input from table B1.

To correct this condition, values of temperature and PET were read from the I-columns straddling the computed I. These points were plotted on a large scale graph and a smooth curve was drawn to represent the relationship for the computed I-value. A tabulation was then made of values from this curve with unadjusted PET read off in three decimals. This tabulation was used in place of the original tabled values in the computations and the resulting curve was smooth throughout the year (fig. 2). Computed daily values are given in table B16.

Palmer and Havens (P6) state that the Thornthwaite method can be represented by the formula

$$PET = 1.6 (10 TC / I)^a$$

where PET is monthly potential evapotranspiration in cm, TC is monthly-mean temperature in °C, I is the heat index (48.02 for Coshocton) and is the sum of 12 monthly index values of i (a function of monthly normal temperatures) and a is an empirically derived exponent which is a function of I

$$a = 0.49 + 0.0179 I - 0.0000771 I^2 + 0.000000675 I^3.$$

These formulas may be used for computerizing the calculation if desired, although a day length correction would also be needed. The program developed by Black (B2) is one example.

The Thornthwaite method is designed for computations of PET for 1 day or for a full month and should therefore be applicable for the durations computed in this report.

Blaney-Criddle Method

The procedure used in computing the Blaney-Criddle PET curve is given in a Soil Conservation Service publication (S1). The general formula is:

$$PET = (0.0173 TA - 0.314) * KC * TA * (DL/4465.6)$$

where TA is mean daily air temperature, (table B1), KC is a crop growth stage coefficient for alfalfa (table B13), and DL is day length in hours (table B11). The constant, 4465.6 is the sum of the day lengths of table B11 for the year. When TA is less than 35.0 degrees, the first term in parenthesis is given a constant value of 0.3.

The Blaney-Criddle method was originally devised for estimating seasonal consumptive use. The modifications as described in the SCS report (S1) are designed to extend the method to give reasonably accurate estimates of consumptive use for short-time periods of from 5 to 30 days. The authors used the term DL/4465.6 to enable estimates to be made on a daily basis.

For July 1, the Blaney-Criddle PET is computed as:

$$PET = (0.0173 * 71.0 - 0.314) * 1.12 * 71.0 * (15.0/4465.6) = 0.244.$$

A tabulation of computed daily values is given in table B17.

Hamon Method

Hamon (H1) derived an equation for computing PET based on possible hours of sunshine and the saturated water vapor density at the daily mean temperature.

His formula is

$$PET = C D^2 PT/100$$

where C is a constant, 0.55, D is the possible hours of sunshine in units of 12 hours (the data of table B11 divided by 12) and PT is the saturated water vapor density (absolute humidity) at the daily mean temperature, divided by 100.

The computing formula is

$$PET = 0.0055 * (DL/12)^2 * (AH * 2.2881).$$

DL is the day length value from table B11. The AH term is obtained by linear interpolation in the 100 percent column of Marvin's table XII (M1) using air temperature from table B1 as the argument. The constant, 2.2881, converts units. For July 1, TA is 71.0 so AH is 8.240 and

$$PET = 0.0055 * (15.0/12)^2 * (8.240 * 2.2881) = 0.162.$$

Computed daily values are given in table B18.

Papadakis Method

Papadakis (P1) suggested that potential evapotranspiration may be computed from the simple formula

$$PET = 0.5625 (e_{ma} - e_{mi-2})$$

where PET is monthly potential evapotranspiration in cm, e_{ma} is the saturation vapor pressure in mb corresponding to the average daily maximum temperature, and e_{mi-2} is the saturated vapor pressure in mb corresponding to the average daily minimum temperature minus 2°C. Papadakis reasoned that 2°C is the usual difference between minimum and dew point temperatures.

Since dew point temperatures are available in this study (table B2), the equation was modified to read

$$E = 0.5625 (e_{ma} - e_{td})$$

where e_{td} is the saturated vapor pressure in mb corresponding to the dew point temperature.

The computing formulas is $PET = 0.2459 (e_{ma} - e_{td})$

where the temperature of ma is found by adding the value of table B12 to that of table B1 and the temperature of td is given in table B2. The constant, 0.2459, is found from

$$0.5625 (0.3937) (33.864) / 30.5 = 0.2459$$

where 0.5625 is the Papadakis constant, 0.3937 converts cm to inches, 33.864 converts inches of mercury to mb and 30.5 is the average number of days in the month.

Using July 1 data, the temperature of m_a is $71.0 \div 10.2 = 81.2$ from which $e_{m_a} = 1.063$ from Marvin's (M1) tables. The temperature of t_d is 62.2 so $e_{t_d} = 0.559$. Then for July 1,

$$PET = 0.2459 (1.063 - 0.559)$$

and $PET = 0.124$ for the day. Computed daily values are given in table B19.

Grassi Method

Grassi (G1) developed a formula for computing evapotranspiration (PET) when measurements of incident radiation were available.

The formula is

$$PET = K C_{Rs} C_T C_{Crc} F.$$

In this formula, K is a constant, 0.537. C_{Rs} is the coefficient for radiation and is computed as 0.000675 RI where RI is radiation from table B5 and the constant converts from langleys to inches of evaporation equivalent. In this formula, C_T takes the linear form, $0.620 + 0.00559 TA$, where TA is air temperature from table B1. The C_{Crc} coefficient representing plant cover was set at 1.0 for the meadow and F equalled 1.09 for alfalfa.

The computing formula for this method is

$$ET = 0.537 * 0.000675 * RI * (0.620 + 0.00559 * TA) * 1.09$$

Using July 1 data,

$$\begin{aligned} ET &= 0.537 * 0.000675 * 581 * (0.620 + 0.00559 * 71.0) * 1.09 \\ &= 0.233. \end{aligned}$$

Daily computed values are given in table B20.

Grassi (G1) mentioned that there was less statistical error in this method and his method using extraterrestrial radiation than in his method using pan evaporation. He also was cautious against using any of the methods for periods of less than a week or two.

Stephens and Stewart Method

Stephens and Stewart (S2) examined several computational methods with Florida data. For PET from grass, they found their fractional evaporation equivalent method ranked highest. They point out that the equation was developed for Florida conditions.

For PET from grass, the Stephens and Stewart formula is

$$PET = (0.0082 TA - 0.19) (RI/1500)$$

where TA and RI are air temperature and solar radiations (tables B1 and B5), respectively. The constants 0.0082 and 0.19 were developed by regression analysis and the 1500 value converts langley's to inches of evaporation.

The computing formula is

$$PET = (0.0082 * TA - 0.19) * (RI/1500).$$

For July 1 when TA = 71.0 and RI = 581, PET is computed as 0.152. Daily computed values are listed in table B21.

The Stephens and Stewart method was devised for monthly estimates.

Turc Method

Turc (T2) derived a formula for PET as

$$PET = 0.40 \text{ TC}(\text{RI} + 50) / (\text{TC} + 15)$$

where TC is air temperature in °C, RI is solar radiation in langley, and PET is in mm per month.

The computing formula is

$$PET = ((0.40 * (5 * (\text{TA} - 32) / 9) * (\text{RI} + 50) / ((5 * (\text{TA} - 32) / 9) + 15)) / (25.4 * 30.5)$$

where TA is air temperature in °F (table B1), RI is solar radiation (table B5), and the last two constants convert to inches per day from mm per month.

Using July 1 data,

$$\begin{aligned} PET &= ((0.40 * (5 * (71.0 - 32.0) / 9) * (581 + 50) / ((5 * (71.0 - 32.0) / 9) + 15)) / (25.4 * 30.5) \\ &= 0.193 \end{aligned}$$

Daily computed values are given in table B22.

The Turc formula was designed to give monthly PET and was modified as above for daily estimates. Note that the formula used in this report is not that originally developed by Turc (T3) but a later development.

Jensen - Haise Method

Jensen - Haise (J2) developed a formula for computing PET based on mean air temperature and solar radiation. Their formula is

$$PET = (0.014 TA - 0.37) RI$$

where TA and RI are air temperature and solar radiation (tables B1 and B5) respectively.

The computing formula is

$$PET = (0.014 * TA - 0.37) * RI * 0.000673$$

where 0.000673 converts from langleys to inches of evaporation equivalent.

Using July 1 data with TA = 71.0 and RI = 581, PET is computed as 0.244.

Daily computed values are given in table B23.

PET in the Jensen - Haise method refers to the ET that can occur in irrigated fields located in arid and semi-arid areas. The estimating equation is based on data for periods greater than 5 days.

Makkink Method

Makkink (RI) developed a formula based on radiation and temperature as

$$PET = 0.61 RI (\Delta / (\Delta + \gamma)) - 0.12$$

where PET is monthly potential evapotranspiration in millimeters, RI is solar radiation in mm per day evaporation equivalent, Δ is the slope of the saturated vapor pressure - temperature curve at the mean air temperature, and γ is the psychrometric constant, 0.27 for degrees Fahrenheit and millimeters of mercury. The fraction was divided through by γ so tabled values of Δ/γ could be used. A short table of Δ/γ (dimension-less) versus temperature ($^{\circ}\text{C}$) was given by van Bavel (V1) and a more extensive table obtained from him is given in table B15.

The computing formula is

$$PET = (0.61 * 0.0171 * RI * (DOG/DOG + 1) - 0.12) * 0.03937$$

where RI is solar radiation in langley (table B5), 0.0171 converts langley to mm of evaporation equivalent, DOG is Δ/γ and is interpolated from table B15 using air temperature from table B1 (converted to $^{\circ}\text{C}$) as the argument, and 0.03937 converts from mm to inches.

Using July 1 data, TA from table B1 is 71.0 so the temperature in $^{\circ}\text{C}$ is 21.67; interpolating in table B15, DOG is 2.342. Then

$$PET = ((0.61 * 0.0171 * 581. * (2.342/3.342)) - 0.12) * 0.03937$$

0.162.

The Makkink formula was designed to predict monthly PET but is used here for daily PET values. Daily computed values are given in table B24.

Christiansen Method

Christiansen (C1) and his students at Utah State University have been developing a method of computing pan evaporation from climatic data. The formula is

$$PET = 0.473 R_T C_T C_W C_H C_S C_E C_M$$

In this formula, 0.473 is a dimensionless constant. R_T is solar radiation at the top of the atmosphere in inches of evaporation equivalent (table B10).

The following formulas for the remaining coefficients were given by Christiansen (C1) in his formulas 64 to 68. C_T is the coefficient for air temperature (table B1) computed as

$$C_T = 0.0673 + 0.0132 TA + 0.0000367 TA^2$$

C_W is the coefficient for wind speed in miles per day at pan height (table B3) computed as

$$C_W = 0.708 + 0.00546 W - 0.00001 W^2$$

C_H is the coefficient for humidity (table B8) computed as

$$C_H = 1.250 - 0.0087 RH + 0.000075 RH^2 - 0.0000000085 RH^4$$

where the value of RH enters the formula as a whole number. C_S is the coefficient for percent of possible sunshine (table B7) computed as

$$C_S = 0.542 + 0.0080 S - 0.000078 S^2 + 0.00000062 S^3$$

where S enters the formula as a whole number. C_E is the coefficient for the elevation of the site (1180 feet) and is computed as $C_E = 0.970 + 0.030 (1.18)$

1.0054 , a constant for this study. C_M is a monthly vegetative coefficient determined empirically. Data from Indiana were taken from a publication by

Christiansen (C2), extrapolated to a full year and graphed on a chart from which daily values were tabulated (table B14).

The computing equation is

$$\begin{aligned} \text{PET} = & 0.473 * \text{REX} * (-0.0673 + 0.0132 * \text{TA} + 0.0000367 * \\ & \text{TA} ** 2) * (0.708 + 0.00546 * \text{W} - 0.00001 * \text{W} ** 2) \\ & * (1.250 - 0.0087 * \text{RH} + 0.000075 * \text{RH} ** 2 - \\ & 0.0000000085 * \text{RH} ** 4) * (0.542 + 0.0080 * \text{S} - \\ & 0.000078 * \text{S} ** 2 + 0.00000062 * \text{S} ** 3) * 1.0054 \\ & * \text{CM}. \end{aligned}$$

Using July 1 data,

$$\begin{aligned} \text{PET} = & 0.473 * 0.663 * (-0.0673 + 0.0132 * 71.0 + \\ & 0.0000367 * 71.0 * 71.0) * (0.708 + 0.00546 * 63.2 - \\ & 0.00001 * 63.2 * 63.2) * (1.250 - 0.0087 * 74 + \\ & 0.000075 * 74 * 74 - 0.0000000085 * 74 * 74 * 74 * 74) \\ & * (0.542 + 0.0080 * 67 - 0.000078 * 67 * 67 + 0.00000062 \\ & * 67 * 67 * 67) * 1.0054 * 0.87 = 0.204. \end{aligned}$$

The Christiansen method was devised to compute monthly values and was modified as above to give daily estimates. Daily computed values are given in table B25.

Penman Method

Penman (P2, P3) combined the energy balance and aerodynamic equations into a single equation for estimating PET. His equation is

$$PET = (\Delta H + E_a \gamma) / (\Delta + \gamma)$$

Where PET is evaporation from a free water surface in mm per day, Δ is the slope of the saturated vapor pressure - temperature curve at the mean air temperature, and γ is the psychrometric constant, 0.27 for °F and mm of mercury. The Δ and H terms are defined below. In order to take advantage of tabled values of Δ/γ (table B15), the equation is divided through by γ giving

$$PET = ((\Delta/\gamma) H + E_a) / ((\Delta/\gamma) + 1).$$

The E_a term of Penman's equation contains the vapor pressure deficit and the wind terms as

$$E_a = 0.35 (e_s - e_d) (1 + u/100)$$

where e_s and e_d are the saturated and actual vapor pressure of the air in mm mercury and u is wind at 2 meter height in miles per day. Since the wind speed data in table B3 are from an anemometer at 2 feet height, the correction

$$u = (\log 6.6 / \log 2.0) W + 2.72 W$$

was used to convert the W-values of table B3 to 2 meter height wind speeds.

This is the original Penman (P7) aerodynamic term which allows for the extra roughness of a crop as compared with open water. Air and dew point temperatures from tables B1 and B2 are used to enter Marvin's tables (M1) to obtain the saturated and actual vapor pressures, VPTA and VPTD, respectively.

The remaining term of Penman's equation, H , is made up of two parts dealing with incoming short wave radiation, the A term, and outgoing long wave radiation (B). The A term is usually computed as

$$A = R_a (1 - r) (0.18 + 0.55 n/N)$$

where A is in units of mm evaporation equivalent per day. R_a is extraterrestrial radiation in the same units as A , r is the albedo and n/N is the ratio of actual to possible hours of sunshine. When solar radiation values are available (table B5), this simplifies to

$$A = RI (1 - r).$$

Outgoing long wave radiation, B , is estimated as

$$B = \sigma TK^4 (0.56 - 0.092 e_d^{0.5}) (0.10 + 0.9 n/N)$$

where σ is the Stefan-Boltzmann constant (0.00000000201), TK is mean air temperature in degrees Kelvin, and e_d is the actual vapor pressure of the air in mm mercury. The H -term consists of A minus B .

The computing formula for the pressure - wind term is

$$EA = 0.35 (25.4) (VPTA - VPTD) (1 + 0.0272 W)$$

where the 25.4 converts pressure to mm Hg. Using July 1 data, $TA = 71.0$ (table B1) so $VPTA = 0.757$; $TD = 62.2$ (table B2) so $VPTD = 0.559$; $W = 63.2$ (table B3), and

$$EA = 0.35 (25.4) (0.757 - 0.559) (1 + 0.0272 (63.2))$$

and $EA = 4.7861$ mm for July 1.

The short wave radiation term is computed as

$$A = 0.0171 RI (1 - ALB)$$

where the 0.0171 converts langley's to mm of evaporation equivalent, RI is solar radiation from table B5, and ALB is from table B9.

Using July 1 data, $RI = 581$, $ALB = 0.20$, and

$$A = 0.0171 (581) (1 - 0.20)$$

and $A = 7.9481$ mm for July 1.

The long wave outgoing radiation term is computed as

$$B = \sigma T_K^4 (0.56 - 0.092 VPTD^{0.5}) (0.10 + 0.9 S) \text{ where}$$

the S values from table B7 are entered as decimals and the other terms are as previously defined. Using July 1 data, $TA = 71.0$ (table B1) and

$$\begin{aligned} \sigma T_a^4 &= 0.00000000201 (5 (71.0 - 32.0) / 9 + 273)^4 \\ &= 15.153749. \end{aligned}$$

$VPTD = 0.559$; converting to mm, $25.4 (0.559) = 14.1986$; $(14.1986)^{0.5} = 3.7681$, and

$$(0.56 - 0.092 (3.7681)) = 0.213335.$$

Since $S = 0.67$ (table B7)

$$(0.10 + 0.9 (0.67)) = 0.703$$

and B is computed as

$$15.153749 (0.213335) (0.703) = 2.2727 \text{ mm.}$$

Since $H = A - B$, $H = 5.6754$ mm for July 1.

Entering table B15 with 21.67°C (from $TA = 71.0^\circ \text{F}$ on July 1),

$\Delta/\gamma = 2.342$. Substituting in the basic equation

$$PET = (((2.342) 5.6754) + 4.7861) / (2.342 + 1)$$

and $PET = 5.4093$ mm or 0.213 inches for July 1.

The Δ/γ term gives more weight to the H -term than to the EA -term during the summer period when PET is high. Results from this method of calculation are listed in table B26.

Van Bavel Method

Van Bavel (V1) improved the combination equation over the Penman version to the point where it does not contain any empirical constants or functions. The Van Bavel version is

$$PET = ((\Delta/\gamma) (H/L) + B_v PD / ((\Delta/\gamma) + 1)).$$

The Δ/γ term was defined in the Penman method. H is the same as defined in the Penman method but is now in units of ly. L is the latent heat of vaporization, 583 ly cm^{-3} . PD is the vapor pressure deficit in mb. B_v is the transport factor and is found from

$$B_v = (0.01222 W / (\ln z_a / z_o)^2) \cdot 298 / TK$$

where W is daily wind speed at 2 m in km per day, z_a is the height above the surface where temperature, humidity, and wind are measured (200 cm), z_o is a roughness parameter (1 cm for alfalfa), and TK is the temperature of the air in degrees Kelvin.

The computing formula for BV is

$$\begin{aligned} BV &= (0.01222 * W * 2.72 * 1.609 * 298 / (28.0722 * (5 * (TA - 32) / \\ &\quad 9) + 273) \\ &= 0.5677 * W / ((5 * (TA - 32) / 9) + 273). \end{aligned}$$

In this formula, 0.01222 is a constant computed from the density of the air, the Von Karman constant, and the ambient pressure, 2.72 converts wind data from 2 feet to 2 m, 1.609 converts wind from miles to km, and 28.0722 is the value of $(\ln 200/1)^2$. Using July 1 data

$$BV = (0.5677 * 63.2) / ((5 * (71.0 - 32.0) / 9) + 273)$$

and $BV = 0.1218 \text{ cm}$.

In the absence of measured net radiation, the H-term used is the same as the one used by Penman; thus, for July 1, $H = 5.6754$ mm which, when divided by 0.0171, converts to 332 ly. Values of H are given in table B6. The vapor pressure deficit term is computed as

$$PD = (VPTA - VPTD) * 33.864$$

where 33.864 converts units from in. Hg to mb. Using July 1 data,

$$PD = (0.757 - 0.559) * 33.864$$

and $PD = 6.7051$ mb.

Substituting in the basic equation,

$$PET = (2.342 (332/583) + 0.1218 (6.7051)) / (2.342 + 1)$$

and $PET = 0.6434$ cm or 0.253 inches for July 1. Computed daily values are given in table B27.

Lake Evaporation

Kohler, Nordenson, and Fox (K1) modified the combination method and presented nomograms for computing both lake and class A pan evaporation. Lamoreux (L1) adapted the formula for computer use and his derivation is briefed in the following. The basic Penman equation may be written as

$$PET = (Q_n \Delta + E_a \gamma) / (\Delta + \gamma)$$

where Q_n is net radiation and γ has the value of 0.0105 inch Hg per °F.

The E_a term of this equation is

$$E_a = (e_s - e_a)^{0.88} (0.37 + 0.0041W)$$

The $Q_n \Delta$ term is computed as

$$Q_n \Delta = \text{EXP} [(TA - 212) (0.1024 - 0.01066 \ln RI)] - 0.0001.$$

The computing equation for lake evaporation is then written as

$$PET = \left[\text{EXP} (TA - 212) (0.1024 - 0.01066 \ln RI) \right] - 0.0001 + \\ 0.0105 (e_s - e_a)^{0.88} (0.37 + 0.0041W) \left[0.015 + \right. \\ (TA + 398.36)^{-2} (6.8554) (10^{10}) \text{EXP} (\\ \left. - 7482.6 / (TA + 398.36) \right) \left. \right]^{-1}$$

In these equations, TA and TD are air and dewpoint temperatures (tables B1 and B2), respectively, R is solar radiation in langley's (table B5) and W is wind at pan height in miles per day (table B3).

Computation with this formula is complex and is best done on an electronic computer. A program which calculates both lake and pan evaporation is available from the Weather Bureau. If only a few values are needed, the nomograms given by Kohler, Nordenson, and Fox (K1) are easy to use. Computed daily values are given in table B2§.

Pan Evaporation

The pan evaporation amounts given in table B37 are computed with the same program which was used for computing lake evaporation. Again, for a few values, the nomograph given in Kohler, Nordenson, and Fox (K1) is easy to use. Computed daily values are given in table B29.

APPENDIX B

This Appendix of the report contains tabular data. Tables B1 to B12 contain climatic data useful in computing PET. Tables B13 to B15 are crop and meteorological data needed in several of the computations. Tables B16 to B29 are the daily PET values computed by the 14 methods while table B30 contains the daily values which comprise the 'standard' lysimeter curve.

TABLE B1.--MEAN DAILY AIR TEMPERATURE.

DATA ARE FROM 4-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

DEGREES FAHRENHEIT

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	27.2	27.5	31.7	42.9	55.9	65.0	71.0	73.4	68.8	59.8	46.7	33.6
2	27.1	27.6	32.0	43.3	56.3	65.2	71.1	73.4	68.6	59.4	46.2	33.2
3	27.1	27.7	32.2	43.8	56.7	65.5	71.3	73.3	68.3	59.1	45.7	32.9
4	27.0	27.8	32.5	44.2	57.0	65.7	71.5	73.3	68.1	58.7	45.3	32.6
5	27.0	27.9	32.7	44.7	57.4	65.9	71.6	73.2	67.8	58.3	44.8	32.3
6	27.0	27.9	33.0	45.1	57.7	66.1	71.8	73.1	67.6	58.0	44.3	31.9
7	26.9	28.0	33.3	45.6	58.1	66.3	71.9	73.1	67.3	57.6	43.9	31.6
8	26.9	28.1	33.6	46.1	58.4	66.6	72.0	73.0	67.0	57.2	43.4	31.4
9	26.9	28.2	33.9	46.5	58.8	66.8	72.2	72.9	66.8	56.8	42.9	31.1
10	26.9	28.3	34.2	47.0	59.1	67.0	72.3	72.8	66.5	56.4	42.4	30.8
11	26.8	28.4	34.5	47.4	59.4	67.2	72.4	72.7	66.2	56.0	42.0	30.5
12	26.8	28.6	34.9	47.9	59.7	67.4	72.5	72.5	65.9	55.6	41.5	30.3
13	26.8	28.7	35.2	48.4	60.0	67.6	72.6	72.4	65.6	55.2	41.1	30.0
14	26.8	28.8	35.5	48.8	60.3	67.8	72.7	72.3	65.3	54.8	40.6	29.8
15	26.8	28.9	35.9	49.2	60.6	68.0	72.8	72.2	65.1	54.3	40.1	29.6
16	26.9	29.1	36.3	49.7	60.9	68.2	72.9	72.0	64.8	53.9	39.7	29.4
17	26.9	29.2	36.6	50.1	61.2	68.4	73.0	71.9	64.5	53.5	39.2	29.2
18	26.9	29.4	37.0	50.6	61.5	68.6	73.1	71.7	64.1	53.1	38.8	29.0
19	26.9	29.5	37.4	51.0	61.8	68.8	73.2	71.5	63.8	52.6	38.4	28.8
20	26.9	29.7	37.8	51.5	62.0	69.0	73.2	71.4	63.5	52.2	37.9	28.6
21	27.0	29.9	38.2	51.9	62.3	69.2	73.3	71.2	63.2	51.7	37.5	28.5
22	27.0	30.0	38.6	52.3	62.6	69.4	73.3	71.0	62.9	51.3	37.1	28.3
23	27.0	30.2	39.0	52.7	62.8	69.6	73.4	70.8	62.6	50.9	36.7	28.1
24	27.1	30.4	39.4	53.2	63.1	69.8	73.4	70.6	62.2	50.4	36.3	28.0
25	27.1	30.6	39.8	53.6	63.3	69.9	73.4	70.4	61.9	49.9	35.8	27.9
26	27.2	30.8	40.2	54.0	63.6	70.1	73.5	70.2	61.6	49.5	35.5	27.8
27	27.2	31.0	40.7	54.4	63.8	70.3	73.5	70.0	61.2	49.0	35.1	27.6
28	27.3	31.2	41.1	54.8	64.1	70.5	73.5	69.8	60.9	48.6	34.7	27.5
29	27.3	31.5	41.5	55.2	64.3	70.6	73.5	69.5	60.5	48.1	34.3	27.5
30	27.4		42.0	55.6	64.5	70.8	73.5	69.3	60.2	47.6	33.9	27.4
31	27.5		42.4		64.8		73.4	69.1		47.2		27.3
AVERAGE	27.0	29.1	36.6	49.4	60.7	68.0	72.7	71.7	64.8	53.8	40.1	29.8

TABLE B2.--MEAN DAILY DEW POINT TEMPERATURE.

DATA ARE FROM 3-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

DEGREES FAHRENHEIT

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	21.1	19.9	23.7	33.4	45.7	56.2	62.2	64.1	60.4	50.8	37.8	27.2
2	21.1	20.0	23.9	33.8	46.1	56.5	62.4	64.1	60.2	50.4	37.4	27.0
3	20.9	20.0	24.1	34.2	46.5	56.8	62.5	64.0	60.0	50.0	37.0	26.7
4	20.8	20.1	24.4	34.6	46.8	57.0	62.6	64.0	59.7	49.6	36.6	26.4
5	20.7	20.1	24.6	35.0	47.2	57.3	62.7	64.0	59.5	49.2	36.2	26.2
6	20.6	20.2	24.9	35.4	47.6	57.5	62.8	63.9	59.2	48.8	35.8	25.9
7	20.6	20.3	25.1	35.8	48.0	57.8	63.0	63.9	59.0	48.4	35.4	25.7
8	20.5	20.3	25.4	36.2	48.4	58.0	63.1	63.8	58.7	48.0	35.0	25.4
9	20.4	20.4	25.7	36.6	48.8	58.3	63.2	63.7	58.4	47.6	34.6	25.2
10	20.3	20.5	25.9	37.0	49.1	58.5	63.2	63.7	58.1	47.1	34.2	25.0
11	20.2	20.6	26.2	37.4	49.5	58.7	63.3	63.6	57.8	46.7	33.8	24.7
12	20.2	20.7	26.5	37.9	49.9	58.9	63.4	63.5	57.5	46.3	33.5	24.5
13	20.1	20.8	26.8	38.3	50.2	59.2	63.5	63.4	57.2	45.9	33.1	24.3
14	20.1	20.9	27.1	38.7	50.5	59.4	63.6	63.3	56.9	45.4	32.7	24.1
15	20.0	21.0	27.4	39.1	50.9	59.6	63.6	63.2	56.6	45.0	32.4	23.9
16	20.0	21.2	27.7	39.5	51.3	59.8	63.7	63.1	56.3	44.6	32.0	23.7
17	19.9	21.3	28.1	39.9	51.6	60.0	63.8	63.0	56.0	44.2	31.7	23.5
18	19.9	21.5	28.4	40.3	52.0	60.2	63.8	62.9	55.6	43.7	31.3	23.3
19	19.9	21.6	28.7	40.8	52.3	60.4	63.9	62.7	55.3	43.3	31.0	23.1
20	19.8	21.8	29.1	41.2	52.6	60.5	63.9	62.6	55.0	42.9	30.6	22.9
21	19.8	21.9	29.4	41.6	53.0	60.7	64.0	62.5	54.6	42.4	30.3	22.8
22	19.8	22.1	29.7	42.0	53.3	60.9	64.0	62.3	54.3	42.0	30.0	22.6
23	19.8	22.3	30.1	42.4	53.6	61.1	64.0	62.2	53.9	41.6	29.6	22.4
24	19.8	22.5	30.4	42.8	53.9	61.2	64.1	62.0	53.5	41.1	29.3	22.3
25	19.8	22.6	30.8	43.2	54.2	61.4	64.1	61.8	53.2	40.7	29.0	22.1
26	19.8	22.8	31.2	43.6	54.5	61.5	64.1	61.6	52.8	40.3	28.7	22.0
27	19.8	23.0	31.5	44.1	54.8	61.7	64.1	61.5	52.4	39.9	28.4	21.8
28	19.8	23.2	31.9	44.5	55.1	61.8	64.1	61.3	52.0	39.5	28.1	21.7
29	19.8	23.5	32.3	44.9	55.4	62.0	64.1	61.1	51.6	39.0	27.8	21.5
30	19.9		32.7	45.3	55.7	62.1	64.1	60.9	51.2	38.6	27.5	21.4
31	19.9		33.0		56.0		64.1	60.6		38.2		21.3
AVERAGE	20.2	21.3	27.2	39.3	51.1	59.5	63.5	62.9	56.2	44.6	32.4	23.9

TABLE B3.--MEAN DAILY WIND MOVEMENT AT PAN HEIGHT.

DATA ARE FROM 3-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

INCHES IN TOP 4 MILES OF LYSIMETER.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	93.6	93.0	94.9	92.4	82.0	70.0	63.2	59.8	60.3	69.0	83.8	93.1
2	93.6	93.1	94.9	92.1	81.6	69.7	63.1	59.7	60.4	69.4	84.3	93.2
3	93.5	93.1	94.9	91.9	81.1	69.4	62.9	59.7	60.6	69.9	84.7	93.4
4	93.4	93.2	95.0	91.6	80.7	69.1	62.8	59.6	60.7	70.3	85.2	93.5
5	93.4	93.2	95.0	91.4	80.3	68.8	62.7	59.5	60.9	70.8	85.6	93.6
6	93.3	93.3	95.0	91.1	79.9	68.5	62.5	59.5	61.1	71.3	86.0	93.7
7	93.3	93.3	95.0	90.8	79.5	68.3	62.4	59.4	61.3	71.7	86.4	93.8
8	93.2	93.4	95.0	90.5	79.0	68.0	62.3	59.4	61.5	72.2	86.8	93.8
9	93.2	93.5	95.0	90.2	78.6	67.7	62.1	59.3	61.7	72.7	87.2	93.9
10	93.1	93.5	95.0	89.9	78.2	67.5	62.0	59.3	61.9	73.2	87.6	94.0
11	93.1	93.6	95.0	89.6	77.8	67.2	61.9	59.3	62.1	73.6	88.0	94.0
12	93.1	93.7	94.9	89.3	77.4	67.0	61.7	59.3	62.4	74.1	88.3	94.0
13	93.0	93.7	94.9	88.9	77.0	66.7	61.6	59.2	62.6	74.6	88.7	94.1
14	93.0	93.8	94.9	88.6	76.6	66.5	61.5	59.2	62.9	75.1	89.0	94.1
15	93.0	93.9	94.8	88.3	76.2	66.2	61.4	59.2	63.2	75.6	89.3	94.1
16	92.9	94.0	94.7	87.9	75.8	66.0	61.3	59.2	63.5	76.1	89.7	94.1
17	92.9	94.0	94.7	87.5	75.4	65.8	61.2	59.2	63.8	76.6	90.0	94.1
18	92.9	94.1	94.6	87.2	75.0	65.6	61.1	59.2	64.1	77.1	90.3	94.1
19	92.9	94.2	94.5	86.8	74.6	65.4	60.9	59.3	64.4	77.6	90.6	94.1
20	92.9	94.3	94.4	86.4	74.2	65.2	60.8	59.3	64.7	78.1	90.8	94.1
21	92.8	94.3	94.3	86.0	73.8	65.0	60.7	59.3	65.1	78.6	91.1	94.1
22	92.8	94.4	94.1	85.7	73.4	64.8	60.6	59.4	65.4	79.1	91.3	94.1
23	92.8	94.5	94.0	85.3	73.1	64.6	60.5	59.4	65.8	79.5	91.6	94.0
24	92.8	94.5	93.9	84.9	72.7	64.4	60.5	59.5	66.2	80.1	91.8	94.0
25	92.9	94.6	93.7	84.5	72.4	64.2	60.4	59.5	66.5	80.6	92.0	93.9
26	92.9	94.7	93.6	84.0	72.0	64.1	60.3	59.6	66.9	81.0	92.2	93.9
27	92.9	94.7	93.4	83.6	71.7	63.9	60.2	59.7	67.3	81.5	92.4	93.9
28	92.9	94.8	93.2	83.2	71.3	63.7	60.1	59.8	67.7	82.0	92.6	93.8
29	92.9	94.8	93.0	82.8	71.0	63.6	60.0	59.9	68.2	82.5	92.8	93.8
30	93.0		92.8	82.4	70.7	63.4	59.9	60.0	68.6	82.9	92.9	93.7
31	93.0		92.6		70.3		59.9	60.1		83.4		93.7
AVERAGE	93.1	93.9	94.4	87.8	75.9	66.3	61.4	59.5	63.7	76.1	89.1	93.9

TABLE 83.--MEAN DAILY WIND MOVEMENT AT PAN HEIGHT.

DATA ARE FROM 3-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-50 DATA
LESS 1956, 1957, 1958, AND PERIODS WHEN MAY CUT RESTRICTED PET ESTIMATE.

MILES

DAY JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEP. OCT. NOV. DEC.

1	23.6	23.0	24.0	25.4	25.0	20.0	23.5	24.8	20.3	24.0	23.8	23.1
2	23.6	23.1	24.0	25.1	21.0	23.1	23.1	20.7	20.4	24.4	24.3	23.5
3	23.2	23.1	24.9	21.9	21.1	20.4	25.9	20.7	20.1	24.7	24.7	23.4
4	23.4	23.2	25.0	21.6	20.7	20.1	25.8	20.6	20.7	20.3	24.5	23.5
5	23.4	23.5	25.0	21.4	20.3	20.8	25.7	24.3	20.9	20.4	24.6	23.6
6	23.3	23.3	25.0	21.1	20.4	20.5	25.5	20.5	20.5	21.1	21.3	24.0
7	23.3	23.3	25.0	20.8	20.5	20.3	25.4	20.4	20.4	21.3	21.7	24.4
8	23.2	23.4	25.0	20.5	20.0	20.0	25.3	20.4	20.4	21.5	21.5	24.8
9	23.2	23.2	25.0	20.5	20.6	20.7	25.1	20.3	20.7	21.7	21.7	24.5
10	23.1	23.2	25.0	20.9	20.5	20.5	25.0	20.3	20.3	21.9	21.5	24.4
11	23.1	23.6	25.0	20.6	20.8	20.5	24.5	20.9	20.3	21.4	21.6	24.0
12	23.1	23.7	24.9	20.3	20.4	20.0	24.7	20.7	20.3	21.4	21.1	24.0
13	23.0	23.7	24.9	20.9	20.9	20.0	24.6	20.7	20.2	21.6	21.6	24.1
14	23.0	23.8	24.9	20.6	20.6	20.5	24.5	20.5	20.2	21.9	21.1	24.0
15	23.0	23.9	24.8	20.3	20.5	20.5	24.4	20.5	20.2	21.5	21.0	24.1
16	22.9	24.0	24.7	20.9	20.8	20.0	24.3	20.5	20.2	21.5	21.1	24.1
17	22.9	24.0	24.7	20.5	20.4	20.8	24.2	20.5	20.3	21.6	21.6	24.1
18	22.9	24.1	24.6	20.5	20.0	20.6	24.1	20.2	20.2	21.1	21.1	24.1
19	22.9	24.2	24.5	20.8	20.4	20.9	24.0	20.3	20.4	21.6	21.6	24.1
20	22.9	24.3	24.4	20.4	20.3	20.5	23.9	20.3	20.3	21.1	21.1	24.1
21	22.8	24.3	24.3	20.0	20.8	20.0	23.8	20.7	20.3	21.1	21.6	24.1
22	22.8	24.4	24.1	20.7	20.4	20.8	23.8	20.8	20.4	21.4	21.4	24.1
23	22.8	24.5	24.0	20.3	20.1	20.6	23.7	20.9	20.4	21.4	21.4	24.0
24	22.8	24.2	23.9	20.9	20.7	20.4	23.7	20.9	20.5	21.4	21.4	24.0
25	22.8	24.3	23.7	20.4	20.4	20.2	23.6	20.9	20.9	21.4	21.4	23.9
26	22.9	24.7	23.6	20.0	20.0	20.1	23.6	20.9	20.6	21.0	21.0	23.9
27	22.9	24.7	23.4	20.6	20.7	20.3	23.5	20.7	20.3	21.2	21.2	23.9
28	22.9	24.8	23.2	20.3	20.3	20.7	23.4	20.1	20.8	21.7	21.7	23.8
29	22.9	24.9	23.0	20.8	21.0	20.6	23.4	20.0	20.9	21.5	21.5	23.8
30	23.0			20.4	20.7	20.4	23.4	20.9	20.0	21.6	21.6	23.7
31	23.0											
AVERAGE	23.1	23.9	24.4	21.8	20.9	20.3	21.4	20.5	20.7	21.1	21.1	23.9

TABLE B4.--MEAN DAILY SOIL MOISTURE.

DATA ARE FROM 5-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

INCHES IN TOP 40 INCHES OF LYSIMETER.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	9.7	11.6	12.2	12.2	10.9	8.5	7.2	6.1	5.3	5.4	5.8	7.3
2	9.8	11.7	12.2	12.2	10.9	8.4	7.2	6.0	5.3	5.4	5.8	7.4
3	9.9	11.7	12.2	12.2	10.8	8.3	7.2	6.0	5.3	5.4	5.9	7.5
4	9.9	11.7	12.2	12.2	10.7	8.3	7.2	6.0	5.3	5.4	5.9	7.5
5	10.0	11.8	12.2	12.2	10.6	8.2	7.1	5.9	5.3	5.4	5.9	7.6
6	10.1	11.8	12.2	12.2	10.5	8.2	7.1	5.9	5.3	5.4	6.0	7.7
7	10.2	11.8	12.2	12.1	10.5	8.1	7.1	5.8	5.3	5.4	6.0	7.8
8	10.2	11.9	12.2	12.1	10.4	8.1	7.0	5.8	5.3	5.4	6.0	7.8
9	10.3	11.9	12.2	12.1	10.3	8.0	7.0	5.8	5.3	5.4	6.1	7.9
10	10.4	11.9	12.2	12.1	10.2	8.0	7.0	5.8	5.3	5.4	6.1	8.0
11	10.5	11.9	12.2	12.0	10.1	7.9	6.9	5.7	5.3	5.4	6.2	8.1
12	10.5	12.0	12.2	12.0	10.0	7.9	6.9	5.7	5.3	5.4	6.2	8.1
13	10.6	12.0	12.2	12.0	9.9	7.8	6.9	5.7	5.3	5.4	6.3	8.2
14	10.7	12.0	12.2	11.9	9.9	7.8	6.8	5.6	5.3	5.5	6.3	8.3
15	10.7	12.0	12.2	11.9	9.8	7.7	6.8	5.6	5.3	5.5	6.4	8.3
16	10.8	12.0	12.2	11.8	9.7	7.7	6.8	5.6	5.3	5.5	6.4	8.4
17	10.9	12.0	12.3	11.8	9.6	7.7	6.7	5.6	5.3	5.5	6.5	8.5
18	10.9	12.1	12.3	11.8	9.5	7.6	6.7	5.5	5.3	5.5	6.5	8.6
19	11.0	12.1	12.3	11.7	9.4	7.6	6.6	5.5	5.3	5.5	6.6	8.7
20	11.0	12.1	12.3	11.7	9.4	7.6	6.6	5.5	5.3	5.5	6.6	8.8
21	11.1	12.1	12.3	11.6	9.3	7.5	6.6	5.5	5.3	5.5	6.7	8.8
22	11.2	12.1	12.3	11.5	9.2	7.5	6.5	5.4	5.3	5.6	6.8	8.9
23	11.2	12.1	12.3	11.5	9.1	7.5	6.5	5.4	5.3	5.6	6.8	9.0
24	11.3	12.1	12.3	11.4	9.0	7.4	6.4	5.4	5.3	5.6	6.9	9.1
25	11.3	12.1	12.3	11.4	9.0	7.4	6.4	5.4	5.3	5.6	6.9	9.2
26	11.4	12.1	12.3	11.3	8.9	7.4	6.4	5.4	5.3	5.6	7.0	9.2
27	11.4	12.2	12.3	11.2	8.8	7.4	6.3	5.4	5.3	5.7	7.1	9.3
28	11.5	12.2	12.3	11.2	8.7	7.3	6.3	5.3	5.3	5.7	7.1	9.4
29	11.5	12.2	12.2	11.1	8.7	7.3	6.2	5.3	5.3	5.7	7.2	9.5
30	11.5		12.2	11.0	8.6	7.3	6.2	5.3	5.3	5.7	7.3	9.5
31	11.6		12.2		8.5		6.1	5.3		5.8		9.6
AVERAGE	10.8	12.0	12.2	11.8	9.7	7.8	6.7	5.6	5.3	5.5	6.4	8.4

TABLE B5.--MEAN DAILY SOLAR RADIATION.

DATA ARE FROM 3-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

LANGLEYS
LANGLEYS

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	153.	211.	286.	383.	486.	566.	581.	538.	459.	354.	233.	155.
2	154.	213.	289.	386.	490.	568.	581.	536.	456.	350.	229.	154.
3	156.	216.	292.	389.	493.	569.	580.	534.	453.	346.	226.	153.
4	157.	218.	295.	393.	496.	571.	579.	532.	450.	342.	222.	152.
5	158.	220.	297.	396.	499.	572.	578.	530.	447.	338.	219.	150.
6	160.	223.	300.	400.	503.	573.	578.	528.	444.	334.	216.	149.
7	161.	225.	303.	403.	506.	574.	577.	526.	440.	330.	212.	149.
8	163.	228.	306.	407.	509.	576.	576.	523.	437.	326.	209.	148.
9	164.	230.	309.	410.	512.	577.	575.	521.	434.	322.	206.	147.
10	166.	233.	312.	414.	515.	578.	574.	519.	430.	318.	203.	146.
11	167.	235.	315.	417.	518.	579.	573.	516.	427.	314.	200.	146.
12	169.	238.	318.	421.	521.	579.	571.	514.	424.	310.	197.	145.
13	171.	240.	321.	424.	523.	580.	570.	511.	420.	306.	194.	145.
14	173.	243.	324.	428.	526.	581.	569.	509.	417.	302.	191.	145.
15	174.	245.	327.	431.	529.	581.	568.	507.	413.	298.	189.	144.
16	176.	248.	330.	435.	532.	582.	566.	504.	410.	294.	186.	144.
17	178.	251.	334.	438.	534.	582.	565.	501.	406.	290.	183.	144.
18	180.	253.	337.	442.	537.	583.	563.	499.	403.	286.	181.	144.
19	182.	256.	340.	445.	539.	583.	562.	496.	399.	282.	178.	144.
20	184.	259.	343.	449.	542.	583.	560.	494.	395.	278.	176.	145.
21	186.	261.	346.	452.	544.	583.	559.	491.	392.	274.	174.	145.
22	188.	264.	349.	456.	547.	583.	557.	488.	388.	270.	171.	145.
23	190.	267.	353.	459.	549.	583.	555.	485.	384.	266.	169.	146.
24	193.	269.	356.	463.	551.	583.	554.	483.	380.	262.	167.	146.
25	195.	272.	359.	466.	553.	583.	552.	480.	377.	259.	165.	147.
26	197.	275.	362.	470.	555.	583.	550.	477.	373.	255.	163.	148.
27	199.	278.	366.	473.	557.	583.	548.	474.	369.	251.	162.	148.
28	201.	280.	369.	476.	559.	583.	546.	471.	365.	247.	160.	149.
29	204.	283.	372.	480.	561.	582.	544.	468.	361.	244.	158.	150.
30	206.		376.	483.	563.	582.	542.	465.	357.	240.	157.	151.
31	208.		379.		565.		540.	462.		236.		152.
AVERAGE	178.	246.	331.	433.	530.	579.	564.	503.	410.	294.	190.	148.

TABLE 86.--MEAN DAILY NET RADIATION, WASH D.C.

(SEE TEXT OF PENMAN METHOD IN APPENDIX A FOR DERIVATION)

LANGLEYS												
DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	20.	67.	120.	181.	244.	318.	332.	304.	239.	150.	65.	29.
2	21.	69.	122.	179.	248.	313.	333.	302.	236.	146.	64.	29.
3	23.	69.	122.	180.	251.	315.	332.	301.	237.	146.	64.	28.
4	23.	71.	125.	183.	251.	316.	331.	299.	234.	142.	62.	27.
5	24.	72.	124.	186.	254.	316.	331.	297.	231.	140.	60.	27.
6	26.	75.	127.	189.	258.	317.	331.	296.	228.	136.	57.	26.
7	27.	76.	129.	192.	259.	319.	331.	294.	226.	133.	56.	27.
8	28.	79.	132.	195.	262.	321.	330.	293.	223.	131.	53.	28.
9	29.	81.	134.	198.	265.	323.	330.	291.	220.	127.	53.	27.
10	31.	83.	134.	195.	268.	322.	329.	290.	216.	123.	50.	26.
11	32.	85.	137.	197.	269.	323.	328.	287.	213.	119.	47.	26.
12	34.	88.	140.	201.	272.	324.	327.	285.	212.	118.	49.	25.
13	35.	89.	139.	203.	274.	325.	327.	282.	208.	114.	47.	25.
14	37.	90.	142.	204.	275.	327.	326.	281.	205.	110.	44.	23.
15	38.	91.	144.	207.	278.	327.	325.	279.	201.	108.	45.	22.
16	39.	94.	147.	211.	281.	328.	324.	276.	198.	105.	42.	22.
17	41.	97.	151.	211.	283.	329.	323.	275.	196.	103.	40.	22.
18	43.	98.	147.	215.	284.	330.	322.	273.	193.	99.	40.	22.
19	44.	101.	150.	217.	286.	331.	321.	270.	189.	96.	37.	22.
20	46.	101.	153.	218.	290.	331.	319.	269.	185.	94.	37.	23.
21	48.	103.	155.	221.	292.	330.	319.	266.	182.	91.	38.	20.
22	49.	103.	157.	225.	295.	330.	317.	263.	180.	87.	35.	20.
23	51.	106.	161.	225.	295.	331.	316.	260.	176.	88.	33.	21.
24	54.	107.	163.	229.	298.	331.	315.	260.	172.	85.	34.	19.
25	53.	110.	166.	230.	300.	332.	315.	257.	169.	84.	32.	20.
26	55.	110.	165.	233.	302.	332.	314.	254.	165.	81.	30.	21.
27	56.	113.	166.	236.	302.	332.	312.	252.	163.	79.	32.	18.
28	58.	114.	169.	237.	304.	332.	310.	249.	159.	76.	30.	19.
29	61.	117.	172.	240.	307.	332.	309.	246.	155.	73.	28.	18.
30	62.		175.	243.	309.	333.	307.	243.	151.	69.	27.	18.
31	64.		177.		311.		306.	241.		68.		19.
AVERAGE	40.	92.	147.	209.	280.	326.	322.	275.	199.	107.	44.	23.

TABLE B7.--MEAN DAILY PERCENT OF POSSIBLE SUNSHINE.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	38.	39.	43.	47.	56.	64.	67.	66.	62.	56.	46.	35.
2	38.	39.	43.	47.	56.	64.	67.	66.	62.	56.	45.	35.
3	38.	40.	44.	48.	56.	64.	67.	66.	62.	56.	45.	35.
4	38.	40.	44.	48.	57.	64.	67.	66.	62.	56.	44.	35.
5	38.	40.	44.	48.	57.	65.	67.	66.	62.	55.	44.	34.
6	38.	40.	44.	48.	57.	65.	67.	66.	62.	55.	44.	34.
7	38.	40.	44.	48.	58.	65.	67.	66.	61.	55.	43.	34.
8	38.	40.	44.	48.	58.	65.	67.	65.	61.	54.	43.	33.
9	38.	40.	44.	48.	58.	65.	67.	65.	61.	54.	42.	33.
10	38.	40.	45.	49.	58.	66.	67.	65.	61.	54.	42.	33.
11	38.	40.	45.	49.	59.	66.	67.	65.	61.	54.	42.	33.
12	38.	40.	45.	49.	59.	66.	67.	65.	60.	53.	41.	33.
13	38.	40.	45.	49.	59.	66.	67.	65.	60.	53.	41.	33.
14	38.	41.	45.	50.	60.	66.	67.	65.	60.	53.	41.	34.
15	38.	41.	45.	50.	60.	66.	67.	65.	60.	52.	40.	34.
16	38.	41.	45.	50.	60.	66.	67.	65.	60.	52.	40.	34.
17	38.	41.	45.	51.	60.	66.	67.	64.	59.	51.	40.	34.
18	38.	41.	46.	51.	61.	66.	67.	64.	59.	51.	39.	34.
19	38.	41.	46.	51.	61.	66.	67.	64.	59.	51.	39.	34.
20	38.	41.	46.	52.	61.	66.	67.	64.	59.	50.	39.	34.
21	38.	41.	46.	52.	61.	67.	67.	64.	59.	50.	38.	35.
22	38.	42.	46.	52.	61.	67.	67.	64.	58.	50.	38.	35.
23	38.	42.	46.	53.	62.	67.	67.	64.	58.	49.	38.	35.
24	38.	42.	46.	53.	62.	67.	67.	63.	58.	49.	37.	36.
25	39.	42.	46.	54.	62.	67.	66.	63.	58.	48.	37.	36.
26	39.	43.	46.	54.	62.	67.	66.	63.	58.	48.	37.	36.
27	39.	43.	47.	54.	63.	67.	66.	63.	57.	47.	36.	37.
28	39.	43.	47.	55.	63.	67.	66.	63.	57.	47.	36.	37.
29	39.	43.	47.	55.	63.	67.	66.	63.	57.	47.	36.	38.
30	39.	43.	47.	55.	63.	67.	66.	63.	57.	47.	36.	38.
31	39.		47.		63.		66.	62.		46.		38.
AVERAGE	38.	41.	45.	51.	60.	66.	67.	64.	60.	52.	40.	35.

TABLE B8.--MEAN DAILY RELATIVE HUMIDITY.

PERCENT												
DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	78.	73.	71.	69.	68.	73.	74.	73.	75.	72.	71.	77.
2	78.	73.	71.	69.	69.	74.	74.	73.	75.	72.	71.	78.
3	77.	73.	72.	69.	69.	74.	74.	73.	75.	72.	71.	78.
4	77.	72.	72.	69.	69.	74.	74.	73.	75.	72.	71.	78.
5	77.	72.	72.	69.	69.	74.	74.	73.	75.	72.	71.	78.
6	76.	72.	72.	69.	69.	74.	74.	73.	75.	72.	72.	78.
7	76.	72.	72.	69.	69.	74.	74.	73.	75.	72.	72.	78.
8	76.	72.	72.	68.	69.	74.	74.	73.	75.	71.	72.	78.
9	76.	72.	71.	68.	69.	74.	74.	73.	75.	71.	72.	78.
10	76.	72.	71.	68.	70.	74.	73.	73.	75.	71.	72.	78.
11	76.	72.	71.	68.	70.	74.	73.	73.	75.	71.	72.	78.
12	76.	72.	71.	68.	70.	74.	73.	73.	75.	71.	72.	79.
13	76.	72.	71.	68.	70.	75.	73.	74.	75.	71.	72.	79.
14	76.	72.	71.	68.	70.	75.	73.	74.	74.	71.	73.	79.
15	75.	72.	71.	68.	70.	75.	73.	74.	74.	71.	74.	79.
16	75.	72.	71.	68.	71.	75.	73.	74.	74.	71.	74.	79.
17	75.	72.	71.	68.	71.	75.	73.	74.	74.	71.	74.	79.
18	75.	72.	71.	68.	71.	75.	73.	74.	74.	71.	74.	79.
19	75.	72.	70.	68.	71.	75.	73.	74.	74.	71.	74.	79.
20	75.	72.	70.	68.	71.	75.	73.	74.	74.	71.	75.	79.
21	74.	72.	70.	68.	71.	75.	73.	74.	73.	71.	75.	79.
22	74.	72.	70.	68.	72.	75.	73.	74.	73.	70.	75.	79.
23	74.	72.	70.	68.	72.	75.	73.	74.	74.	70.	75.	79.
24	74.	72.	70.	68.	72.	75.	73.	74.	73.	70.	75.	79.
25	74.	72.	70.	68.	72.	75.	73.	74.	73.	70.	75.	79.
26	73.	72.	70.	68.	72.	75.	73.	74.	73.	71.	75.	79.
27	73.	72.	70.	68.	73.	75.	73.	74.	73.	71.	76.	79.
28	73.	72.	70.	68.	73.	75.	73.	75.	73.	71.	77.	79.
29	73.	72.	70.	68.	73.	75.	73.	75.	73.	71.	77.	78.
30	73.		69.	68.	73.	74.	73.	75.	72.	71.	77.	78.
31	73.		69.		73.		73.	75.		71.		78.
AVERAGE	75.	72.	71.	68.	71.	75.	73.	74.	74.	71.	74.	79.

TABLE B10.--DAILY EXTRA-TERRESTRIAL RADIATION

FROM MARVIN'S AT 40 DEGREES NORTH LATITUDE.

INCHES OF EVAPORATION EQUIVALENT.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.214	.285	.388	.501	.585	.656	.663	.613	.536	.423	.316	.233
2	.214	.289	.392	.503	.588	.658	.661	.610	.534	.419	.313	.231
3	.215	.293	.395	.505	.591	.660	.659	.607	.531	.415	.310	.229
4	.216	.298	.399	.507	.594	.661	.658	.604	.529	.411	.307	.227
5	.217	.303	.403	.509	.597	.663	.657	.602	.527	.407	.303	.226
6	.219	.308	.407	.511	.600	.664	.656	.599	.524	.403	.300	.224
7	.220	.313	.411	.513	.603	.664	.655	.596	.521	.399	.297	.222
8	.222	.318	.414	.516	.606	.665	.653	.593	.518	.395	.294	.220
9	.223	.322	.418	.518	.609	.665	.652	.591	.515	.391	.291	.218
10	.225	.327	.421	.521	.612	.666	.651	.589	.512	.387	.288	.216
11	.227	.331	.425	.524	.615	.667	.650	.586	.509	.383	.285	.215
12	.229	.335	.429	.527	.618	.668	.649	.584	.506	.379	.282	.214
13	.231	.338	.432	.530	.620	.669	.648	.583	.502	.375	.278	.212
14	.233	.342	.436	.533	.622	.670	.646	.582	.498	.371	.275	.212
15	.235	.345	.440	.536	.625	.670	.645	.580	.494	.367	.272	.212
16	.237	.348	.444	.539	.627	.671	.643	.578	.491	.363	.269	.211
17	.239	.351	.448	.542	.629	.671	.641	.576	.487	.359	.265	.211
18	.241	.354	.452	.546	.631	.672	.639	.574	.483	.355	.262	.211
19	.243	.357	.456	.550	.633	.672	.637	.572	.479	.351	.259	.210
20	.245	.360	.460	.554	.635	.672	.636	.570	.474	.348	.256	.210
21	.248	.363	.463	.557	.637	.672	.634	.568	.469	.345	.253	.210
22	.251	.367	.467	.560	.639	.672	.632	.565	.464	.342	.250	.210
23	.254	.370	.471	.563	.641	.672	.630	.563	.460	.340	.248	.210
24	.257	.373	.475	.566	.643	.672	.628	.560	.456	.338	.246	.211
25	.260	.376	.478	.569	.645	.671	.626	.557	.451	.335	.244	.211
26	.262	.379	.481	.572	.646	.670	.624	.554	.446	.332	.242	.212
27	.265	.382	.485	.574	.647	.669	.622	.551	.441	.329	.241	.212
28	.269	.384	.488	.576	.649	.667	.620	.548	.437	.326	.239	.213
29	.273	.386	.491	.579	.651	.666	.618	.545	.432	.324	.237	.213
30	.277		.494	.582	.653	.665	.617	.542	.427	.321	.235	.214
31	.281		.498		.654		.615	.539		.319		.214
AVERAGE	.240	.341	.444	.539	.624	.667	.641	.577	.488	.366	.272	.216

TABLE B12.--DIFFERENCES BETWEEN DAILY MAXIMUM AND MEAN AIR TEMPERATURES.

DATA ARE FROM 3-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE

DEGREES FAHRENHEIT

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	6.8	7.4	8.1	9.1	10.2	10.6	10.2	10.1	10.7	10.5	8.9	7.2
2	6.8	7.4	8.1	9.1	10.2	10.6	10.2	10.1	10.7	10.5	8.8	7.2
3	6.8	7.4	8.2	9.2	10.2	10.6	10.2	10.2	10.7	10.4	8.8	7.1
4	6.8	7.5	8.2	9.2	10.2	10.6	10.2	10.2	10.7	10.4	8.7	7.1
5	6.8	7.5	8.2	9.2	10.3	10.6	10.2	10.2	10.7	10.4	8.6	7.1
6	6.8	7.5	8.3	9.3	10.3	10.6	10.2	10.2	10.7	10.3	8.6	7.0
7	6.9	7.5	8.3	9.3	10.3	10.6	10.2	10.2	10.7	10.3	8.5	7.0
8	6.9	7.6	8.3	9.3	10.3	10.6	10.1	10.2	10.7	10.2	8.4	7.0
9	6.9	7.6	8.3	9.4	10.4	10.5	10.1	10.2	10.7	10.2	8.4	7.0
10	6.9	7.6	8.4	9.4	10.4	10.5	10.1	10.3	10.7	10.2	8.3	6.9
11	6.9	7.6	8.4	9.5	10.4	10.5	10.1	10.3	10.8	10.1	8.2	6.9
12	6.9	7.7	8.4	9.5	10.4	10.5	10.1	10.3	10.8	10.1	8.2	6.9
13	7.0	7.7	8.5	9.5	10.4	10.5	10.1	10.3	10.8	10.0	8.1	6.9
14	7.0	7.7	8.5	9.6	10.5	10.5	10.1	10.3	10.8	10.0	8.1	6.8
15	7.0	7.7	8.5	9.6	10.5	10.5	10.1	10.3	10.8	9.9	8.0	6.8
16	7.0	7.8	8.5	9.6	10.5	10.5	10.1	10.4	10.7	9.9	7.9	6.8
17	7.0	7.8	8.6	9.7	10.5	10.4	10.1	10.4	10.7	9.8	7.9	6.8
18	7.1	7.8	8.6	9.7	10.5	10.4	10.1	10.4	10.7	9.7	7.8	6.8
19	7.1	7.8	8.6	9.8	10.5	10.4	10.1	10.4	10.7	9.7	7.8	6.8
20	7.1	7.9	8.7	9.8	10.6	10.4	10.1	10.4	10.7	9.6	7.7	6.8
21	7.1	7.9	8.7	9.8	10.6	10.4	10.1	10.5	10.7	9.6	7.7	6.8
22	7.2	7.9	8.7	9.9	10.6	10.4	10.1	10.5	10.7	9.5	7.6	6.8
23	7.2	7.9	8.8	9.9	10.6	10.4	10.1	10.5	10.7	9.5	7.6	6.8
24	7.2	8.0	8.8	9.9	10.6	10.3	10.1	10.5	10.7	9.4	7.5	6.8
25	7.2	8.0	8.8	10.0	10.6	10.3	10.1	10.5	10.6	9.3	7.5	6.8
26	7.2	8.0	8.9	10.0	10.6	10.3	10.1	10.6	10.6	9.3	7.4	6.8
27	7.3	8.0	8.9	10.0	10.6	10.3	10.1	10.6	10.6	9.2	7.4	6.8
28	7.3	8.1	8.9	10.1	10.6	10.3	10.1	10.6	10.6	9.1	7.3	6.8
29	7.3	8.1	9.0	10.1	10.6	10.3	10.1	10.6	10.5	9.1	7.3	6.8
30	7.3		9.0	10.1	10.6	10.2	10.1	10.6	10.5	9.0	7.2	6.8
31	7.4		9.0		10.6		10.1	10.6		8.9		6.8
AVERAGE	7.0	7.7	8.6	9.6	10.5	10.5	10.1	10.4	10.7	9.8	8.0	6.9

TABLE B13.--DAILY VALUES OF BLANEY-CRIDDLE CROP GROWTH STAGE COEFFICIENTS.

FROM ALFALFA CURVE, FIGURE 2, IN SCS TECH. RELEASE NO. 21 (51).

MEAN MONTHLY COEFFICIENTS FOR INDIANA.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	0.60	0.68	0.80	0.93	1.04	1.12	1.12	1.09	1.03	0.96	0.86	0.70
2	0.60	0.68	0.80	0.94	1.05	1.12	1.12	1.08	1.03	0.96	0.85	0.70
3	0.60	0.69	0.81	0.94	1.05	1.12	1.12	1.08	1.03	0.96	0.85	0.69
4	0.60	0.69	0.81	0.94	1.05	1.12	1.12	1.08	1.03	0.95	0.84	0.69
5	0.60	0.69	0.82	0.95	1.05	1.12	1.12	1.08	1.02	0.95	0.84	0.68
6	0.61	0.70	0.82	0.95	1.06	1.12	1.12	1.08	1.02	0.95	0.83	0.68
7	0.61	0.70	0.82	0.96	1.06	1.13	1.12	1.08	1.02	0.94	0.83	0.67
8	0.61	0.70	0.83	0.96	1.06	1.13	1.12	1.08	1.02	0.94	0.82	0.67
9	0.61	0.71	0.83	0.97	1.07	1.13	1.12	1.07	1.02	0.94	0.82	0.67
10	0.61	0.71	0.84	0.97	1.07	1.13	1.12	1.07	1.01	0.94	0.81	0.66
11	0.62	0.72	0.84	0.97	1.07	1.13	1.12	1.07	1.01	0.93	0.81	0.66
12	0.62	0.72	0.85	0.98	1.08	1.13	1.12	1.07	1.01	0.93	0.80	0.66
13	0.62	0.72	0.85	0.98	1.08	1.13	1.11	1.07	1.01	0.93	0.79	0.65
14	0.62	0.73	0.85	0.98	1.08	1.13	1.11	1.07	1.00	0.92	0.79	0.65
15	0.63	0.73	0.86	0.99	1.08	1.13	1.11	1.06	1.00	0.92	0.78	0.64
16	0.63	0.74	0.86	0.99	1.09	1.13	1.11	1.06	1.00	0.92	0.77	0.64
17	0.63	0.74	0.87	0.99	1.09	1.13	1.11	1.06	1.00	0.91	0.77	0.64
18	0.63	0.74	0.87	1.00	1.09	1.13	1.11	1.06	0.99	0.91	0.76	0.64
19	0.64	0.75	0.88	1.00	1.09	1.13	1.11	1.06	0.99	0.91	0.75	0.63
20	0.64	0.75	0.88	1.01	1.10	1.13	1.10	1.06	0.99	0.90	0.75	0.63
21	0.64	0.76	0.89	1.01	1.10	1.13	1.10	1.05	0.99	0.90	0.74	0.62
22	0.64	0.76	0.89	1.01	1.10	1.13	1.10	1.05	0.99	0.90	0.74	0.62
23	0.65	0.77	0.89	1.02	1.10	1.13	1.10	1.05	0.98	0.89	0.73	0.62
24	0.65	0.77	0.90	1.02	1.10	1.13	1.10	1.05	0.98	0.89	0.73	0.62
25	0.65	0.77	0.90	1.02	1.11	1.13	1.10	1.05	0.98	0.88	0.72	0.61
26	0.66	0.78	0.90	1.03	1.11	1.13	1.09	1.04	0.97	0.88	0.72	0.61
27	0.66	0.78	0.91	1.03	1.11	1.13	1.09	1.04	0.97	0.88	0.71	0.61
28	0.66	0.79	0.92	1.03	1.11	1.13	1.09	1.04	0.97	0.87	0.71	0.60
29	0.67	0.79	0.92	1.04	1.11	1.13	1.09	1.04	0.97	0.87	0.71	0.60
30	0.67		0.92	1.04	1.11	1.13	1.09	1.04	0.96	0.86	0.70	0.60
31	0.68		0.93		1.12		1.09	1.03		0.86		0.60
AVERAGE	0.63	0.73	0.86	0.99	1.08	1.13	1.11	1.06	1.00	0.91	0.78	0.64

TABLE B14.--DAILY VALUES REPLACING CHRISTIANSEN'S MONTHLY COEFFICIENTS.
VALUES OBTAINED BY INTERPOLATION AND EXTRAPOLATION OF CHRISTIANSEN'S
MEAN MONTHLY COEFFICIENTS FOR INDIANA.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	1.12	1.04	.96	.89	.89	.87	.87	.89	.95	1.04	1.10	1.15
2	1.12	1.04	.96	.89	.88	.87	.87	.89	.95	1.04	1.11	1.15
3	1.12	1.03	.96	.89	.88	.87	.88	.89	.96	1.04	1.11	1.15
4	1.11	1.03	.96	.89	.88	.87	.88	.89	.96	1.04	1.11	1.15
5	1.11	1.03	.95	.89	.88	.87	.88	.89	.96	1.05	1.12	1.15
6	1.11	1.02	.95	.89	.88	.87	.88	.89	.96	1.05	1.12	1.15
7	1.11	1.02	.95	.89	.88	.87	.88	.90	.97	1.05	1.12	1.15
8	1.10	1.02	.95	.89	.88	.87	.88	.90	.97	1.05	1.12	1.16
9	1.10	1.02	.94	.89	.88	.87	.88	.90	.97	1.06	1.12	1.16
10	1.10	1.02	.94	.89	.88	.87	.88	.90	.98	1.06	1.13	1.16
11	1.10	1.01	.94	.89	.88	.87	.88	.90	.98	1.06	1.13	1.16
12	1.09	1.01	.94	.89	.88	.87	.88	.90	.98	1.06	1.13	1.16
13	1.09	1.01	.93	.89	.88	.87	.88	.90	.98	1.07	1.13	1.16
14	1.09	1.01	.93	.89	.88	.87	.88	.91	.99	1.07	1.13	1.16
15	1.09	1.00	.93	.89	.88	.87	.88	.91	.99	1.07	1.13	1.16
16	1.08	1.00	.93	.89	.88	.87	.88	.91	.99	1.07	1.13	1.16
17	1.08	1.00	.93	.89	.88	.87	.88	.91	1.00	1.07	1.13	1.16
18	1.08	1.00	.92	.89	.88	.87	.88	.92	1.00	1.08	1.14	1.16
19	1.08	.99	.92	.89	.88	.87	.88	.92	1.00	1.08	1.14	1.16
20	1.07	.99	.92	.89	.88	.87	.88	.92	1.01	1.08	1.14	1.16
21	1.07	.99	.92	.89	.88	.87	.88	.92	1.01	1.08	1.14	1.16
22	1.07	.99	.92	.89	.88	.87	.88	.92	1.01	1.08	1.14	1.16
23	1.07	.98	.91	.89	.88	.87	.88	.93	1.01	1.09	1.14	1.17
24	1.06	.98	.91	.89	.88	.87	.88	.93	1.02	1.09	1.14	1.17
25	1.06	.98	.91	.89	.87	.87	.88	.93	1.02	1.09	1.14	1.17
26	1.06	.97	.91	.89	.87	.87	.89	.94	1.02	1.09	1.14	1.17
27	1.05	.97	.91	.89	.87	.87	.89	.94	1.02	1.09	1.15	1.17
28	1.05	.97	.91	.89	.87	.87	.89	.94	1.03	1.09	1.15	1.17
29	1.05	.97	.91	.89	.87	.87	.89	.94	1.03	1.10	1.15	1.17
30	1.05		.90	.89	.87	.87	.89	.94	1.03	1.10	1.15	1.17
31	1.04		.90		.87		.89	.95		1.10		1.17
VG.	1.08	1.00	.93	.89	.88	.87	.88	.91	.99	1.07	1.13	1.16

TABLE B15.--DELTA / GAMMA (DIMENSIONLESS) VS. TEMPERATURE IN DEGREES CELSIUS.
 FURNISHED BY U.S. WATER CONSERVATION LABORATORY, USDA, ARS, SWC, PHOENIX, ARIZ

TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G
-5.0	.487	-2.0	.592	1.0	.716	4.0	.862	7.0	1.033	10.0	1.232
-4.9	.491	-1.9	.596	1.1	.721	4.1	.868	7.1	1.039	10.1	1.239
-4.8	.494	-1.8	.599	1.2	.725	4.2	.873	7.2	1.045	10.2	1.246
-4.7	.497	-1.7	.603	1.3	.730	4.3	.878	7.3	1.052	10.3	1.254
-4.6	.501	-1.6	.607	1.4	.735	4.4	.884	7.4	1.058	10.4	1.261
-4.5	.504	-1.5	.611	1.5	.739	4.5	.889	7.5	1.064	10.5	1.268
-4.4	.508	-1.4	.615	1.6	.744	4.6	.895	7.6	1.071	10.6	1.275
-4.3	.511	-1.3	.618	1.7	.748	4.7	.900	7.7	1.077	10.7	1.283
-4.2	.514	-1.2	.623	1.8	.753	4.8	.905	7.8	1.083	10.8	1.290
-4.1	.517	-1.1	.627	1.9	.758	4.9	.911	7.9	1.090	10.9	1.297
-4.0	.520	-1.0	.631	2.0	.762	5.0	.916	8.0	1.096	11.0	1.305
-3.9	.524	-0.9	.635	2.1	.767	5.1	.922	8.1	1.102	11.1	1.312
-3.8	.527	-0.8	.639	2.2	.772	5.2	.928	8.2	1.109	11.2	1.320
-3.7	.531	-0.7	.643	2.3	.777	5.3	.933	8.3	1.116	11.3	1.328
-3.6	.534	-0.6	.647	2.4	.782	5.4	.939	8.4	1.122	11.4	1.335
-3.5	.537	-0.5	.651	2.5	.787	5.5	.945	8.5	1.129	11.5	1.343
-3.4	.541	-0.4	.655	2.6	.791	5.6	.950	8.6	1.136	11.6	1.351
-3.3	.544	-0.3	.660	2.7	.796	5.7	.956	8.7	1.142	11.7	1.359
-3.2	.548	-0.2	.664	2.8	.801	5.8	.962	8.8	1.149	11.8	1.366
-3.1	.551	-0.1	.668	2.9	.806	5.9	.967	8.9	1.155	11.9	1.374
-3.0	.555	0.0	.672	3.0	.811	6.0	.973	9.0	1.162	12.0	1.382
-2.9	.558	0.1	.677	3.1	.816	6.1	.979	9.1	1.169	12.1	1.390
-2.8	.562	0.2	.681	3.2	.821	6.2	.985	9.2	1.176	12.2	1.398
-2.7	.566	0.3	.686	3.3	.826	6.3	.991	9.3	1.183	12.3	1.406
-2.6	.569	0.4	.690	3.4	.831	6.4	.997	9.4	1.190	12.4	1.414
-2.5	.573	0.5	.694	3.5	.837	6.5	1.003	9.5	1.197	12.5	1.422
-2.4	.577	0.6	.699	3.6	.842	6.6	1.009	9.6	1.204	12.6	1.430
-2.3	.580	0.7	.703	3.7	.847	6.7	1.015	9.7	1.211	12.7	1.438
-2.2	.584	0.8	.707	3.8	.852	6.8	1.021	9.8	1.218	12.8	1.446
-2.1	.588	0.9	.712	3.9	.857	6.9	1.027	9.9	1.225	12.9	1.454

TABLE B15 CONT.--DELTA / GAMMA VS. TEMPERATURE IN DEGREES CELSIUS.

TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G
13.0	1.462	16.0	1.727	19.0	2.033	22.0	2.382	25.0	2.781	28.0	3.232
13.1	1.470	16.1	1.737	19.1	2.044	22.1	2.395	25.1	2.795	28.1	3.249
13.2	1.479	16.2	1.747	19.2	2.055	22.2	2.408	25.2	2.809	28.2	3.265
13.3	1.487	16.3	1.757	19.3	2.066	22.3	2.420	25.3	2.824	28.3	3.281
13.4	1.496	16.4	1.766	19.4	2.078	22.4	2.433	25.4	2.838	28.4	3.298
13.5	1.504	16.5	1.776	19.5	2.089	22.5	2.446	25.5	2.853	28.5	3.314
13.6	1.513	16.6	1.786	19.6	2.100	22.6	2.459	25.6	2.867	28.6	3.330
13.7	1.521	16.7	1.796	19.7	2.111	22.7	2.471	25.7	2.882	28.7	3.347
13.8	1.529	16.8	1.805	19.8	2.122	22.8	2.484	25.8	2.896	28.8	3.363
13.9	1.538	16.9	1.815	19.9	2.133	22.9	2.497	25.9	2.910	28.9	3.380
14.0	1.546	17.0	1.825	20.0	2.145	23.0	2.509	26.0	2.925	29.0	3.396
14.1	1.555	17.1	1.835	20.1	2.156	23.1	2.523	26.1	2.940	29.1	3.413
14.2	1.564	17.2	1.845	20.2	2.168	23.2	2.536	26.2	2.955	29.2	3.430
14.3	1.573	17.3	1.856	20.3	2.179	23.3	2.549	26.3	2.970	29.3	3.447
14.4	1.582	17.4	1.866	20.4	2.191	23.4	2.563	26.4	2.985	29.4	3.464
14.5	1.591	17.5	1.876	20.5	2.203	23.5	2.576	26.5	3.000	29.5	3.481
14.6	1.600	17.6	1.886	20.6	2.214	23.6	2.589	26.6	3.015	29.6	3.498
14.7	1.609	17.7	1.896	20.7	2.226	23.7	2.602	26.7	3.030	29.7	3.515
14.8	1.618	17.8	1.906	20.8	2.237	23.8	2.616	26.8	3.046	29.8	3.532
14.9	1.627	17.9	1.917	20.9	2.249	23.9	2.629	26.9	3.061	29.9	3.549
15.0	1.635	18.0	1.927	21.0	2.261	24.0	2.642	27.0	3.076	30.0	3.566
15.1	1.645	18.1	1.937	21.1	2.273	24.1	2.656	27.1	3.091	30.1	3.584
15.2	1.654	18.2	1.948	21.2	2.285	24.2	2.670	27.2	3.107	30.2	3.602
15.3	1.663	18.3	1.959	21.3	2.297	24.3	2.684	27.3	3.123	30.3	3.620
15.4	1.672	18.4	1.969	21.4	2.309	24.4	2.698	27.4	3.138	30.4	3.638
15.5	1.681	18.5	1.980	21.5	2.321	24.5	2.711	27.5	3.154	30.5	3.656
15.6	1.691	18.6	1.990	21.6	2.334	24.6	2.725	27.6	3.170	30.6	3.674
15.7	1.700	18.7	2.001	21.7	2.346	24.7	2.739	27.7	3.185	30.7	3.692
15.8	1.709	18.8	2.012	21.8	2.358	24.8	2.753	27.8	3.201	30.8	3.710
15.9	1.718	18.9	2.022	21.9	2.370	24.9	2.767	27.9	3.217	30.9	3.727

TABLE B15 CONT.--DELTA / GAMMA VS. TEMPERATURE IN DEGREES CELSIUS.

TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G	TC	D/G
31.0	3.745	33.5	4.222	36.0	4.746	38.5	5.325	41.0	5.958	43.5	6.654
31.1	3.764	33.6	4.242	36.1	4.768	38.6	5.349	41.1	5.985	43.6	6.683
31.2	3.782	33.7	4.262	36.2	4.791	38.7	5.373	41.2	6.012	43.7	6.713
31.3	3.801	33.8	4.282	36.3	4.813	38.8	5.397	41.3	6.039	43.8	6.742
31.4	3.819	33.9	4.302	36.4	4.836	38.9	5.421	41.4	6.066	43.9	6.771
31.5	3.838	34.0	4.322	36.5	4.858	39.0	5.445	41.5	6.093	44.0	6.800
31.6	3.856	34.1	4.343	36.6	4.881	39.1	5.470	41.6	6.120	44.1	6.830
31.7	3.874	34.2	4.364	36.7	4.903	39.2	5.496	41.7	6.147	44.2	6.860
31.8	3.893	34.3	4.384	36.8	4.925	39.3	5.521	41.8	6.174	44.3	6.890
31.9	3.911	34.4	4.405	36.9	4.948	39.4	5.546	41.9	6.201	44.4	6.920
32.0	3.930	34.5	4.426	37.0	4.970	39.5	5.571	42.0	6.228	44.5	6.950
32.1	3.949	34.6	4.447	37.1	4.994	39.6	5.596	42.1	6.256	44.6	6.980
32.2	3.968	34.7	4.467	37.2	5.017	39.7	5.622	42.2	6.284	44.7	7.011
32.3	3.987	34.8	4.488	37.3	5.041	39.8	5.647	42.3	6.312	44.8	7.041
32.4	4.007	34.9	4.509	37.4	5.064	39.9	5.672	42.4	6.340	44.9	7.071
32.5	4.026	35.0	4.530	37.5	5.087	40.0	5.697	42.5	6.368		
32.6	4.045	35.1	4.551	37.6	5.111	40.1	5.723	42.6	6.396		
32.7	4.065	35.2	4.573	37.7	5.134	40.2	5.749	42.7	6.424		
32.8	4.084	35.3	4.595	37.8	5.158	40.3	5.776	42.8	6.452		
32.9	4.103	35.4	4.616	37.9	5.181	40.4	5.802	42.9	6.480		
33.0	4.122	35.5	4.638	38.0	5.204	40.5	5.828	43.0	6.508		
33.1	4.142	35.6	4.660	38.1	5.228	40.6	5.854	43.1	6.538		
33.2	4.162	35.7	4.681	38.2	5.253	40.7	5.880	43.2	6.567		
33.3	4.182	35.8	4.703	38.3	5.277	40.8	5.906	43.3	6.596		
33.4	4.202	35.9	4.724	38.4	5.301	40.9	5.932	43.4	6.625		
33.5	4.222	36.0	4.746	38.5	5.325	41.0	5.958	43.5	6.654		
33.6	4.242	36.1	4.768	38.6	5.349	41.1	5.985	43.6	6.683		
33.7	4.262	36.2	4.791	38.7	5.373	41.2	6.012	43.7	6.713		
33.8	4.282	36.3	4.813	38.8	5.397	41.3	6.039	43.8	6.742		
33.9	4.302	36.4	4.836	38.9	5.421	41.4	6.066	43.9	6.771		
34.0	4.322	36.5	4.858	39.0	5.445	41.5	6.093	44.0	6.800		
34.1	4.343	36.6	4.881	39.1	5.470	41.6	6.120	44.1	6.830		
34.2	4.364	36.7	4.903	39.2	5.496	41.7	6.147	44.2	6.860		
34.3	4.384	36.8	4.925	39.3	5.521	41.8	6.174	44.3	6.890		
34.4	4.405	36.9	4.948	39.4	5.546	41.9	6.201	44.4	6.920		
34.5	4.426	37.0	4.970	39.5	5.571	42.0	6.228	44.5	6.950		
34.6	4.447	37.1	4.994	39.6	5.596	42.1	6.256	44.6	6.980		
34.7	4.467	37.2	5.017	39.7	5.622	42.2	6.284	44.7	7.011		
34.8	4.488	37.3	5.041	39.8	5.647	42.3	6.312	44.8	7.041		
34.9	4.509	37.4	5.064	39.9	5.672	42.4	6.340	44.9	7.071		
35.0	4.530	37.5	5.087	40.0	5.697	42.5	6.368				
35.1	4.551	37.6	5.111	40.1	5.723	42.6	6.396				
35.2	4.573	37.7	5.134	40.2	5.749	42.7	6.424				
35.3	4.595	37.8	5.158	40.3	5.776	42.8	6.452				
35.4	4.616	37.9	5.181	40.4	5.802	42.9	6.480				
35.5	4.638	38.0	5.204	40.5	5.828	43.0	6.508				
35.6	4.660	38.1	5.228	40.6	5.854	43.1	6.538				
35.7	4.681	38.2	5.253	40.7	5.880	43.2	6.567				
35.8	4.703	38.3	5.277	40.8	5.906	43.3	6.596				
35.9	4.724	38.4	5.301	40.9	5.932	43.4	6.625				
36.0	4.746	38.5	5.325	41.0	5.958	43.5	6.654				
36.1	4.768	38.6	5.349	41.1	5.985	43.6	6.683				
36.2	4.791	38.7	5.373	41.2	6.012	43.7	6.713				
36.3	4.813	38.8	5.397	41.3	6.039	43.8	6.742				
36.4	4.836	38.9	5.421	41.4	6.066	43.9	6.771				
36.5	4.858	39.0	5.445	41.5	6.093	44.0	6.800				
36.6	4.881	39.1	5.470	41.6	6.120	44.1	6.830				
36.7	4.903	39.2	5.496	41.7	6.147	44.2	6.860				
36.8	4.925	39.3	5.521	41.8	6.174	44.3	6.890				
36.9	4.948	39.4	5.546	41.9	6.201	44.4	6.920				
37.0	4.970	39.5	5.571	42.0	6.228	44.5	6.950				
37.1	4.994	39.6	5.596	42.1	6.256	44.6	6.980				
37.2	5.017	39.7	5.622	42.2	6.284	44.7	7.011				
37.3	5.041	39.8	5.647	42.3	6.312	44.8	7.041				
37.4	5.064	39.9	5.672	42.4	6.340	44.9	7.071				
37.5	5.087	40.0	5.697	42.5	6.368						
37.6	5.111	40.1	5.723	42.6	6.396						
37.7	5.134	40.2	5.749	42.7	6.424						
37.8	5.158	40.3	5.776	42.8	6.452						
37.9	5.181	40.4	5.802	42.9	6.480						
38.0	5.204	40.5	5.828	43.0	6.508						
38.1	5.228	40.6	5.854	43.1	6.538						
38.2	5.253	40.7	5.880	43.2	6.567						
38.3	5.277	40.8	5.906	43.3	6.596						
38.4	5.301	40.9	5.932	43.4	6.625						
38.5	5.325	41.0	5.958	43.5	6.654						
38.6	5.349	41.1	5.985	43.6	6.683						
38.7	5.373	41.2	6.012	43.7	6.713						
38.8	5.397	41.3	6.039	43.8	6.742						
38.9	5.421	41.4	6.066	43.9	6.771						
39.0	5.445	41.5	6.093	44.0	6.800						
39.1	5.470	41.6	6.120	44.1	6.830						
39.2	5.496	41.7	6.147	44.2	6.860						
39.3	5.521	41.8	6.174	44.3	6.890						
39.4	5.546	41.9	6.201	44.4	6.920						
39.5	5.571	42.0	6.228	44.5	6.950						
39.6	5.596	42.1	6.256	44.6	6.980						
39.7	5.622	42.2	6.284	44.7	7.011						
39.8	5.647	42.3	6.312	44.8	7.041						
39.9	5.672	42.4	6.340	44.9	7.071						
40.0	5.697	42.5	6.368								
40.1	5.723	42.6	6.396								
40.2	5.749	42.7	6.424								
40.3	5.776	42.8	6.452								
40.4	5.802	42.9	6.480								
40.5	5.828	43.0	6.508								
40.6	5.854	43.1	6.538								
40.7	5.880	43.2	6.567								
40.8	5.906	43.3	6.596								
40.9	5.932	43.4	6.625								
41.0	5.958	43.5	6.654								
41.1	5.985	43.6	6.683								
41.2	6.012	43.7	6.713								
41.3	6.039	43.8	6.742								
41.4	6.066	43.9	6.771								
41.5	6.093	44.0	6.800								
41.6	6.120	44.1	6.830								
41.7	6.147	44.2	6.860								
41.8	6.174	44.3	6.890								
41.9	6.201	44.4	6.920								
42.0	6.228	44.5	6.950								
42.1	6.256	44.6	6.980								
42.2	6.284	44.7	7.011								
42.3	6.312	44.8	7.041								
42.4	6.340	44.9	7.071								
42.5	6.368										
42.6	6.396										
42.7	6.424										
42.8	6.452										
42.9	6.480										
43.0	6.508										
43.1	6.538										
43.2	6.567										
43.3	6.596										
43.4	6.625										
43.5	6.654										
43.6	6.683										
43.7	6.713										
43.8	6.742										
43.9	6.771										
44.0	6.800										
44.1	6.830										
44.2	6.860										
44.3	6.890										
44.4	6.920										
44.5	6.950										
44.6	6.980										
44.7	7.011										
44.8	7.041										

TABLE B16.--DAILY POTENTIAL EVAPOTRANSPIRATION, THORNTHWAITE.

VALUES COMPUTED FROM SMOOTHED MEAN DAILY AIR TEMPERATURE DATA.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.000	.000	.000	.029	.087	.138	.172	.177	.140	.088	.036	.002
2	.000	.000	.000	.031	.088	.140	.172	.177	.138	.086	.034	.002
3	.000	.000	.000	.033	.089	.141	.174	.174	.136	.084	.032	.002
4	.000	.000	.001	.034	.091	.142	.174	.174	.135	.082	.031	.001
5	.000	.000	.001	.036	.094	.144	.174	.174	.134	.080	.029	.001
6	.000	.000	.002	.037	.095	.144	.175	.172	.132	.080	.028	.000
7	.000	.000	.003	.040	.096	.145	.176	.172	.130	.077	.028	.000
8	.000	.000	.003	.041	.099	.148	.176	.172	.129	.076	.026	.000
9	.000	.000	.004	.043	.100	.149	.177	.172	.127	.074	.024	.000
10	.000	.000	.004	.046	.101	.151	.178	.169	.125	.073	.023	.000
11	.000	.000	.005	.048	.105	.152	.180	.169	.124	.071	.021	.000
12	.000	.000	.006	.049	.106	.154	.178	.168	.122	.068	.019	.000
13	.000	.000	.006	.052	.108	.154	.178	.168	.120	.068	.018	.000
14	.000	.000	.007	.053	.109	.155	.180	.166	.118	.066	.017	.000
15	.000	.000	.008	.055	.112	.156	.180	.164	.116	.065	.016	.000
16	.000	.000	.009	.058	.114	.158	.181	.163	.115	.063	.015	.000
17	.000	.000	.010	.059	.115	.159	.179	.162	.113	.061	.013	.000
18	.000	.000	.011	.061	.117	.159	.179	.161	.111	.059	.013	.000
19	.000	.000	.012	.063	.119	.160	.180	.158	.110	.057	.012	.000
20	.000	.000	.013	.065	.120	.161	.180	.158	.107	.056	.010	.000
21	.000	.000	.014	.067	.121	.162	.180	.157	.106	.054	.010	.000
22	.000	.000	.015	.069	.123	.164	.180	.154	.105	.052	.009	.000
23	.000	.000	.016	.071	.124	.165	.180	.153	.102	.051	.008	.000
24	.000	.000	.017	.073	.126	.166	.180	.152	.101	.050	.007	.000
25	.000	.000	.018	.075	.127	.168	.180	.152	.100	.048	.006	.000
26	.000	.000	.020	.078	.128	.168	.180	.150	.097	.045	.006	.000
27	.000	.000	.022	.079	.130	.169	.179	.149	.096	.044	.005	.000
28	.000	.000	.023	.080	.133	.170	.179	.148	.094	.042	.004	.000
29	.000	.000	.024	.083	.134	.170	.179	.145	.092	.040	.004	.000
30	.000		.026	.084	.135	.171	.177	.144	.091	.039	.003	.000
31	.000		.028		.136		.177	.143		.038		.000
AVERAGE	.000	.000	1.692	4.683	5.017	1.937	.008					
			.328	3.482	5.514	3.466	.507					

TABLE B18.--DAILY POTENTIAL EVAPOTRANSPIRATION, HAMON.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.013	.016	.023	.045	.084	.130	.162	.159	.115	.069	.035	.018
2	.013	.016	.024	.045	.086	.131	.163	.157	.113	.067	.034	.017
3	.013	.016	.024	.047	.088	.134	.161	.156	.112	.067	.033	.017
4	.013	.016	.024	.048	.089	.135	.162	.156	.111	.065	.033	.017
5	.013	.016	.025	.048	.090	.136	.163	.154	.108	.064	.031	.017
6	.013	.017	.025	.050	.092	.136	.164	.153	.107	.063	.031	.017
7	.013	.017	.026	.051	.094	.137	.165	.153	.105	.061	.030	.016
8	.013	.017	.026	.052	.096	.139	.165	.150	.104	.060	.029	.016
9	.013	.017	.027	.053	.097	.140	.166	.150	.101	.059	.029	.016
10	.013	.017	.027	.055	.098	.142	.164	.149	.100	.058	.028	.015
11	.014	.018	.028	.056	.101	.143	.165	.147	.098	.057	.027	.015
12	.014	.018	.029	.057	.102	.144	.165	.146	.097	.055	.027	.015
13	.014	.018	.029	.059	.103	.145	.166	.143	.096	.054	.026	.015
14	.014	.018	.030	.060	.105	.146	.167	.143	.094	.053	.025	.015
15	.014	.018	.030	.061	.106	.147	.165	.143	.093	.052	.025	.014
16	.014	.019	.031	.062	.107	.148	.165	.140	.091	.050	.024	.014
17	.014	.019	.032	.064	.108	.149	.166	.139	.090	.050	.024	.014
18	.014	.019	.033	.065	.111	.150	.166	.136	.087	.048	.023	.014
19	.014	.020	.033	.066	.112	.151	.165	.135	.086	.047	.023	.014
20	.014	.020	.034	.068	.113	.152	.165	.135	.084	.047	.022	.014
21	.014	.020	.035	.069	.116	.153	.165	.132	.083	.045	.022	.014
22	.014	.020	.035	.071	.117	.154	.165	.131	.082	.044	.021	.014
23	.015	.021	.036	.072	.118	.155	.163	.128	.080	.043	.021	.013
24	.015	.021	.037	.074	.119	.156	.163	.128	.079	.042	.020	.013
25	.015	.021	.038	.076	.121	.156	.163	.127	.077	.041	.020	.013
26	.015	.022	.039	.077	.122	.157	.162	.124	.076	.040	.020	.013
27	.015	.022	.040	.079	.123	.158	.162	.123	.075	.039	.019	.013
28	.015	.023	.040	.080	.124	.159	.162	.121	.073	.038	.019	.013
29	.015	.023	.041	.081	.127	.160	.162	.120	.072	.036	.019	.013
30	.015		.043	.084	.128	.161	.159	.119	.070	.037	.018	.013
31	.015		.043		.129		.159	.116		.036		.013
AVERAGE		.545		1.875		4.404		4.313		1.587		.455
	.433		.987		3.326		5.075		2.759		.758	

TABLE B19.--DAILY POTENTIAL EVAPOTRANSPIRATION, PAPADAKIS.

COMPUTED FROM SOLAR RADIATION INCHES AND AIR TEMPERATURE.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
01	.021	.025	.030	.048	.082	.106	.124	.135	.119	.091	.053	.027
02	.021	.025	.031	.049	.083	.107	.124	.135	.118	.090	.052	.027
03	.021	.025	.031	.050	.084	.107	.125	.135	.116	.087	.051	.026
04	.021	.025	.031	.051	.085	.108	.126	.135	.116	.087	.049	.026
05	.021	.025	.031	.052	.085	.108	.127	.134	.114	.086	.048	.026
06	.021	.025	.032	.053	.087	.109	.128	.134	.114	.085	.047	.025
07	.021	.025	.032	.054	.088	.109	.128	.134	.113	.082	.046	.024
08	.022	.026	.033	.056	.089	.111	.127	.134	.112	.083	.045	.025
09	.022	.026	.033	.056	.090	.110	.129	.133	.111	.082	.044	.024
10	.022	.026	.034	.058	.090	.111	.129	.133	.110	.081	.042	.023
11	.022	.026	.034	.059	.092	.112	.130	.133	.110	.079	.042	.023
12	.022	.026	.035	.060	.092	.112	.130	.132	.109	.078	.041	.023
13	.022	.026	.035	.061	.093	.113	.131	.131	.108	.076	.040	.023
14	.022	.027	.035	.063	.095	.113	.131	.131	.107	.076	.039	.023
15	.022	.027	.036	.063	.095	.114	.132	.130	.107	.074	.037	.022
16	.022	.027	.036	.064	.096	.115	.132	.130	.105	.073	.037	.022
17	.023	.027	.037	.066	.097	.115	.133	.130	.104	.072	.036	.022
18	.023	.028	.037	.067	.097	.115	.134	.128	.103	.071	.035	.022
19	.023	.027	.038	.068	.098	.116	.134	.128	.102	.069	.034	.022
20	.023	.028	.039	.070	.099	.117	.134	.127	.101	.068	.033	.022
21	.023	.028	.040	.071	.100	.118	.134	.127	.101	.067	.033	.022
22	.024	.028	.040	.072	.101	.118	.134	.126	.100	.065	.032	.022
23	.024	.028	.041	.073	.101	.119	.135	.125	.099	.065	.032	.021
24	.024	.029	.042	.075	.102	.119	.135	.124	.098	.063	.031	.021
25	.024	.029	.042	.076	.102	.120	.135	.123	.096	.061	.030	.022
26	.024	.029	.043	.077	.103	.120	.136	.123	.096	.060	.030	.022
27	.024	.029	.044	.077	.103	.121	.136	.122	.095	.059	.029	.021
28	.025	.030	.045	.079	.105	.122	.136	.121	.094	.058	.028	.021
29	.025	.030	.045	.080	.105	.122	.136	.120	.092	.057	.028	.021
30	.024	.030	.046	.081	.105	.123	.136	.119	.092	.055	.027	.021
31	.025	.	.047	.106	.106	.123	.135	.119	.135	.054	.050	.021
AVERAGE	.703	.782	1.155	1.929	2.950	3.430	4.076	3.991	3.162	2.254	1.151	.712

TABLE B20.--DAILY POTENTIAL EVAPOTRANSPIRATION, GRASSI.

COMPUTED FROM SOLAR RADIATION AND AIR TEMPERATURE.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.047	.064	.090	.130	.179	.220	.233	.219	.182	.133	.081	.049
2	.047	.065	.091	.131	.181	.221	.234	.218	.181	.132	.079	.049
3	.048	.066	.092	.133	.182	.222	.233	.217	.179	.130	.078	.049
4	.048	.067	.093	.135	.184	.223	.233	.216	.178	.128	.077	.048
5	.048	.067	.094	.136	.185	.223	.233	.215	.176	.126	.075	.047
6	.049	.068	.095	.138	.187	.224	.233	.215	.175	.125	.074	.047
7	.049	.069	.096	.139	.189	.225	.233	.214	.173	.123	.072	.047
8	.050	.070	.098	.141	.190	.226	.233	.212	.172	.121	.071	.046
9	.050	.071	.099	.142	.192	.226	.232	.211	.170	.119	.070	.046
10	.050	.072	.100	.144	.193	.227	.232	.211	.168	.117	.069	.046
11	.051	.072	.101	.146	.195	.228	.232	.209	.167	.116	.067	.046
12	.051	.073	.102	.148	.196	.228	.231	.208	.166	.114	.066	.045
13	.052	.074	.104	.149	.197	.229	.231	.207	.164	.112	.065	.045
14	.053	.075	.105	.151	.199	.229	.231	.206	.162	.111	.064	.045
15	.053	.076	.106	.152	.200	.230	.230	.205	.160	.109	.063	.045
16	.054	.077	.107	.154	.202	.230	.230	.204	.159	.107	.062	.045
17	.054	.078	.108	.156	.203	.230	.229	.202	.157	.105	.061	.045
18	.055	.078	.110	.158	.204	.231	.229	.201	.156	.104	.060	.044
19	.055	.079	.111	.159	.206	.231	.228	.200	.154	.102	.059	.044
20	.056	.080	.113	.161	.207	.232	.228	.199	.152	.100	.058	.045
21	.057	.081	.114	.162	.208	.232	.227	.197	.151	.098	.057	.045
22	.057	.082	.115	.164	.210	.232	.227	.196	.149	.097	.056	.045
23	.058	.083	.117	.166	.211	.232	.226	.195	.147	.095	.055	.045
24	.059	.084	.118	.168	.212	.233	.225	.194	.145	.093	.054	.045
25	.059	.085	.119	.169	.213	.233	.225	.192	.144	.092	.053	.045
26	.060	.086	.121	.171	.214	.233	.224	.191	.142	.090	.053	.045
27	.061	.087	.123	.173	.215	.233	.223	.189	.140	.089	.052	.045
28	.061	.088	.124	.174	.216	.234	.222	.188	.138	.087	.052	.045
29	.062	.089	.125	.176	.217	.233	.222	.186	.137	.085	.051	.046
30	.063		.127	.178	.218	.234	.221	.185	.135	.084	.050	.046
31	.064	.237	.128	.187	.219	.242	.220	.184		1.082		.046
AVERAGE	1.681	2.206	3.346	4.604	6.224	6.864	7.090	6.286	4.779	3.326	1.904	1.421

TABLE B21.--DAILY POTENTIAL EVAPOTRANSPIRATION, STEPHENS-STEWART.

INCHES

DAY	DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.	YFC
1	1	.003	.005	.013	.041	.087	.129	.152	.148	.114	.071	.030	.009	.004
2	2	.003	.005	.014	.042	.089	.131	.152	.147	.113	.069	.029	.008	.004
3	3	.003	.005	.014	.044	.090	.132	.153	.146	.112	.068	.028	.008	.003
4	4	.003	.006	.015	.045	.092	.133	.153	.146	.111	.066	.027	.008	.002
5	5	.003	.006	.015	.047	.093	.134	.153	.145	.109	.065	.026	.007	.001
6	6	.003	.006	.016	.048	.095	.134	.154	.144	.108	.064	.025	.007	.000
7	7	.003	.006	.017	.049	.097	.135	.154	.144	.106	.062	.024	.007	.000
8	8	.003	.006	.017	.051	.098	.137	.154	.142	.105	.061	.023	.007	.000
9	9	.003	.006	.018	.052	.100	.138	.154	.142	.104	.059	.022	.006	.000
10	10	.003	.007	.019	.054	.101	.138	.154	.141	.102	.058	.021	.006	.000
11	11	.003	.007	.020	.055	.103	.139	.154	.140	.100	.056	.021	.006	.000
12	12	.003	.007	.020	.057	.104	.140	.154	.139	.099	.055	.020	.006	.000
13	13	.003	.007	.021	.058	.105	.141	.154	.138	.097	.054	.019	.005	.000
14	14	.003	.007	.022	.060	.107	.142	.154	.137	.096	.052	.018	.005	.000
15	15	.003	.008	.023	.061	.108	.142	.154	.136	.095	.051	.017	.005	.000
16	16	.004	.008	.024	.063	.110	.143	.154	.135	.093	.049	.017	.005	.000
17	17	.004	.008	.025	.064	.111	.144	.154	.133	.092	.048	.016	.005	.000
18	18	.004	.009	.025	.066	.113	.145	.154	.132	.090	.047	.015	.005	.000
19	19	.004	.009	.026	.068	.114	.145	.154	.131	.089	.045	.015	.004	.000
20	20	.004	.009	.027	.070	.115	.146	.153	.130	.087	.044	.014	.004	.000
21	21	.004	.010	.028	.071	.116	.147	.153	.129	.086	.043	.014	.004	.000
22	22	.004	.010	.029	.073	.118	.147	.153	.128	.084	.042	.013	.004	.000
23	23	.004	.010	.031	.074	.119	.148	.152	.126	.083	.040	.012	.004	.000
24	24	.004	.011	.032	.076	.120	.149	.152	.125	.081	.039	.012	.004	.000
25	25	.004	.011	.033	.078	.121	.149	.152	.124	.080	.038	.011	.004	.000
26	26	.004	.011	.034	.079	.123	.150	.151	.123	.078	.037	.011	.004	.000
27	27	.004	.012	.035	.081	.124	.150	.151	.121	.077	.035	.011	.004	.000
28	28	.005	.012	.036	.082	.125	.151	.150	.120	.075	.034	.010	.004	.000
29	29	.005	.013	.037	.084	.126	.151	.150	.119	.074	.032	.010	.004	.000
30	30	.005		.039	.086	.127	.152	.149	.117	.072	.032	.009	.003	.000
31	31	.005		.040		.129		.148	.116		.031		.003	.000
AVERAGE		.113	.237	1.879	4.262	4.733	4.144	1.547	.165					.016
			.765	3.380		2.812		.540						

TABLE B22.--DAILY POTENTIAL EVAPOTRANSPIRATION, TURC.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.000	.000	.000	.064	.130	.178	.193	.184	.152	.106	.052	.006
2	.000	.000	.000	.066	.132	.176	.193	.183	.150	.104	.050	.004
3	.000	.000	.001	.069	.134	.177	.193	.182	.149	.102	.048	.003
4	.000	.000	.003	.071	.136	.178	.193	.182	.148	.101	.046	.002
5	.000	.000	.005	.074	.137	.179	.193	.181	.146	.099	.045	.001
6	.000	.000	.006	.076	.139	.180	.193	.180	.145	.097	.043	.000
7	.000	.000	.008	.078	.141	.180	.193	.179	.143	.095	.041	.000
8	.000	.000	.010	.081	.143	.182	.193	.178	.142	.094	.040	.000
9	.000	.000	.012	.083	.145	.182	.193	.178	.141	.092	.038	.000
10	.000	.000	.014	.086	.146	.183	.193	.177	.139	.090	.036	.000
11	.000	.000	.016	.088	.148	.184	.193	.176	.138	.088	.035	.000
12	.000	.000	.018	.090	.149	.184	.192	.175	.136	.087	.033	.000
13	.000	.000	.020	.092	.151	.185	.192	.174	.135	.085	.032	.000
14	.000	.000	.022	.095	.152	.186	.192	.173	.133	.083	.030	.000
15	.000	.000	.025	.097	.154	.186	.192	.172	.132	.081	.028	.000
16	.000	.000	.027	.099	.155	.187	.192	.171	.130	.080	.027	.000
17	.000	.000	.029	.101	.157	.187	.191	.170	.129	.078	.025	.000
18	.000	.000	.031	.104	.158	.188	.191	.169	.127	.076	.024	.000
19	.000	.000	.034	.106	.160	.189	.191	.167	.125	.074	.023	.000
20	.000	.000	.036	.108	.161	.189	.190	.167	.124	.072	.021	.000
21	.000	.000	.038	.110	.162	.189	.190	.165	.122	.071	.020	.000
22	.000	.000	.040	.112	.164	.190	.190	.164	.121	.069	.018	.000
23	.000	.000	.043	.114	.165	.190	.189	.163	.119	.067	.017	.000
24	.000	.000	.045	.117	.166	.191	.189	.162	.117	.065	.015	.000
25	.000	.000	.047	.118	.167	.191	.188	.161	.116	.064	.014	.000
26	.000	.000	.050	.121	.168	.191	.188	.159	.114	.062	.013	.000
27	.000	.000	.052	.122	.169	.192	.187	.158	.112	.060	.011	.000
28	.000	.000	.055	.124	.171	.192	.186	.157	.111	.058	.010	.000
29	.000	.000	.057	.126	.172	.192	.186	.155	.109	.057	.008	.000
30	.000	.002	.059	.128	.173	.192	.185	.154	.107	.055	.007	.000
31	.000	.002	.062	.131	.174		.184	.153		.053	.001	.000
AVG.	.000	.000	.179	2.920	4.779	5.567	5.908	5.269	3.912	2.465	.850	.016

TABLE B23.--DAILY POTENTIAL EVAPOTRANSPIRATION, JENSEN-HAISE.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.001	.002	.014	.059	.135	.206	.244	.238	.183	.111	.045	.010
2	.001	.002	.015	.061	.138	.207	.245	.237	.181	.109	.043	.010
3	.001	.003	.016	.064	.141	.209	.245	.236	.179	.107	.041	.009
4	.001	.003	.017	.066	.143	.211	.246	.235	.177	.104	.039	.009
5	.001	.003	.018	.068	.146	.213	.246	.234	.174	.101	.038	.008
6	.001	.003	.019	.070	.148	.214	.247	.232	.172	.099	.036	.008
7	.001	.003	.020	.073	.151	.216	.247	.231	.169	.097	.035	.007
8	.001	.004	.021	.075	.153	.218	.247	.229	.167	.095	.033	.007
9	.001	.004	.022	.078	.156	.219	.248	.228	.165	.092	.032	.006
10	.001	.004	.023	.080	.159	.221	.248	.227	.162	.090	.031	.006
11	.001	.004	.024	.082	.161	.222	.248	.225	.160	.087	.029	.006
12	.001	.005	.025	.085	.163	.224	.248	.223	.158	.085	.028	.005
13	.001	.005	.027	.088	.165	.225	.248	.221	.155	.083	.027	.005
14	.001	.005	.028	.090	.168	.226	.248	.220	.153	.081	.026	.005
15	.001	.006	.029	.092	.170	.228	.248	.219	.150	.078	.024	.004
16	.001	.006	.031	.095	.173	.229	.248	.216	.148	.076	.023	.004
17	.001	.007	.032	.098	.175	.230	.248	.215	.146	.074	.022	.004
18	.001	.007	.034	.101	.177	.232	.248	.213	.143	.072	.021	.003
19	.001	.007	.035	.103	.180	.233	.248	.211	.140	.070	.020	.003
20	.001	.008	.037	.106	.182	.234	.247	.209	.138	.068	.019	.003
21	.001	.009	.038	.108	.184	.235	.247	.207	.136	.065	.018	.003
22	.001	.009	.040	.111	.186	.236	.246	.205	.133	.063	.017	.003
23	.001	.009	.042	.114	.188	.237	.246	.203	.131	.061	.016	.002
24	.001	.010	.044	.117	.190	.238	.245	.201	.128	.059	.016	.002
25	.001	.011	.045	.119	.192	.239	.244	.199	.126	.057	.015	.002
26	.001	.011	.047	.122	.194	.240	.244	.197	.124	.055	.014	.002
27	.001	.012	.049	.125	.196	.241	.243	.195	.121	.053	.013	.002
28	.002	.013	.051	.127	.198	.242	.242	.192	.119	.052	.012	.002
29	.002	.014	.053	.130	.200	.242	.241	.190	.116	.048	.012	.002
30	.002		.055	.133	.202	.243	.240	.188	.114	.048	.011	.001
31	.002		.057		.204		.239	.186		.046		.001
AVERAGE		.189	2.840		6.810		6.662		2.386			.144
	.035	1.008		5.318		7.619		4.468		.756		

TABLE B24.--DAILY POTENTIAL EVAPOTRANSPIRATION, MAKKINK.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.021	.030	.042	.073	.115	.152	.162	.153	.125	.086	.045	.022
2	.021	.030	.043	.074	.116	.150	.163	.153	.124	.085	.044	.021
3	.021	.031	.044	.075	.117	.151	.163	.152	.122	.083	.043	.021
4	.021	.031	.045	.077	.119	.152	.162	.151	.121	.082	.042	.021
5	.021	.032	.045	.078	.120	.152	.162	.151	.120	.081	.041	.020
6	.022	.032	.046	.079	.122	.153	.163	.150	.119	.079	.040	.020
7	.022	.032	.047	.081	.123	.153	.163	.149	.118	.078	.039	.020
8	.022	.033	.048	.082	.124	.154	.162	.148	.116	.077	.038	.020
9	.022	.033	.048	.083	.125	.155	.162	.148	.115	.075	.037	.020
10	.023	.034	.049	.085	.127	.156	.162	.147	.114	.074	.036	.019
11	.023	.034	.050	.086	.128	.156	.162	.146	.113	.072	.035	.019
12	.023	.035	.051	.088	.129	.156	.162	.145	.112	.071	.034	.019
13	.023	.035	.052	.089	.130	.157	.161	.144	.110	.070	.033	.019
14	.024	.035	.053	.091	.131	.158	.161	.143	.109	.068	.033	.019
15	.024	.036	.054	.092	.133	.158	.161	.143	.108	.067	.032	.019
16	.024	.036	.055	.093	.134	.159	.161	.142	.107	.066	.031	.019
17	.025	.037	.056	.095	.135	.159	.161	.141	.105	.064	.030	.019
18	.025	.037	.057	.096	.136	.159	.160	.140	.104	.063	.029	.019
19	.025	.038	.058	.097	.137	.160	.160	.139	.102	.061	.029	.019
20	.026	.038	.059	.099	.138	.160	.159	.138	.101	.060	.028	.019
21	.026	.038	.060	.100	.139	.160	.159	.137	.100	.059	.027	.019
22	.026	.039	.061	.102	.140	.161	.159	.136	.098	.058	.027	.019
23	.027	.039	.062	.103	.141	.161	.158	.134	.097	.056	.026	.019
24	.027	.040	.063	.105	.142	.161	.158	.134	.096	.055	.025	.019
25	.027	.040	.064	.106	.143	.161	.157	.133	.095	.054	.025	.020
26	.028	.041	.065	.108	.144	.162	.157	.132	.093	.053	.024	.020
27	.028	.041	.067	.109	.145	.162	.156	.130	.092	.051	.024	.020
28	.028	.041	.068	.110	.146	.162	.156	.129	.090	.050	.023	.020
29	.029	.042	.069	.112	.147	.162	.155	.128	.089	.049	.023	.020
30	.029		.070	.113	.147	.162	.154	.127	.087	.048	.022	.020
31	.030		.072		.149		.154	.126		.047		.020
AVERAGE		.973	2.784		4.725		4.370		2.044			.574
	.668	1.723		4.122		4.958		3.206		.966		

TABLE B25.--DAILY POTENTIAL EVAPOTRANSPIRATION, CHRISTIANSEN.

COMPUTED USING INCHES

DAY JAN. FEB. MAR. APR. MAY JUNE JULY AUG. SEP. OCT. NOV. DEC.

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.023	.031	.049	.089	.149	.185	.204	.200	.163	.124	.073	.033
2	.023	.031	.050	.091	.147	.184	.204	.199	.162	.122	.072	.032
3	.023	.032	.051	.093	.149	.185	.206	.198	.162	.120	.070	.031
4	.023	.033	.052	.094	.152	.186	.206	.197	.161	.118	.068	.030
5	.023	.034	.052	.096	.153	.188	.206	.196	.160	.117	.067	.030
6	.023	.034	.053	.097	.155	.189	.207	.194	.159	.115	.065	.029
7	.023	.035	.054	.099	.158	.189	.207	.195	.158	.113	.063	.028
8	.023	.035	.055	.102	.159	.191	.206	.193	.156	.112	.062	.028
9	.023	.036	.057	.103	.161	.191	.206	.192	.155	.111	.060	.027
10	.024	.037	.058	.106	.161	.193	.209	.191	.155	.109	.059	.027
11	.024	.037	.059	.107	.163	.194	.209	.190	.153	.108	.058	.026
12	.024	.038	.061	.109	.165	.195	.209	.188	.150	.105	.056	.025
13	.024	.038	.061	.111	.166	.193	.209	.185	.149	.104	.055	.025
14	.024	.039	.062	.113	.169	.193	.209	.186	.150	.102	.053	.025
15	.025	.039	.064	.115	.170	.194	.209	.185	.149	.100	.050	.025
16	.025	.040	.065	.117	.169	.195	.208	.184	.147	.098	.049	.024
17	.025	.040	.067	.119	.171	.195	.208	.182	.146	.096	.048	.024
18	.025	.041	.068	.121	.173	.196	.208	.183	.144	.095	.047	.024
19	.026	.041	.070	.123	.174	.197	.207	.181	.142	.093	.046	.024
20	.025	.042	.072	.126	.175	.197	.207	.180	.141	.091	.044	.023
21	.026	.043	.073	.128	.177	.199	.206	.179	.141	.089	.042	.023
22	.027	.044	.075	.130	.176	.200	.206	.178	.138	.089	.041	.023
23	.027	.044	.075	.132	.178	.200	.205	.178	.135	.088	.041	.023
24	.027	.045	.077	.134	.179	.201	.205	.176	.136	.086	.040	.023
25	.028	.045	.078	.137	.178	.201	.203	.174	.134	.084	.039	.023
26	.028	.046	.080	.139	.179	.201	.204	.175	.132	.082	.038	.023
27	.028	.047	.082	.140	.179	.201	.204	.173	.129	.080	.037	.023
28	.029	.047	.084	.143	.180	.201	.203	.169	.128	.078	.035	.023
29	.029	.048	.085	.145	.181	.201	.202	.167	.126	.078	.034	.024
30	.030	.048	.087	.146	.182	.204	.202	.166	.126	.076	.034	.024
31	.030	.049	.089	.148	.183	.204	.201	.165	.125	.074	.033	.024
AVERAGE	1.142	3.505	5.839	5.699	3.057	.028	.796					
	.787	2.065	5.211	6.385	4.387	1.546						

TABLE B26.--DAILY POTENTIAL EVAPOTRANSPIRATION, PENMAN.

COMPUTED USING PAN ALBEDO.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.028	.046	.069	.106	.152	.185	.203	.190	.152	.108	.066	.038
2	.029	.047	.070	.106	.154	.186	.203	.193	.151	.106	.065	.037
3	.030	.047	.070	.107	.156	.187	.203	.192	.151	.106	.063	.036
4	.029	.048	.072	.109	.157	.188	.204	.191	.150	.104	.063	.036
5	.030	.048	.071	.111	.159	.188	.204	.190	.147	.103	.061	.036
6	.031	.049	.072	.113	.160	.189	.204	.189	.146	.102	.059	.035
7	.030	.050	.073	.115	.161	.189	.204	.188	.145	.100	.059	.035
8	.031	.051	.075	.118	.162	.191	.204	.187	.143	.099	.057	.035
9	.031	.051	.076	.119	.164	.192	.204	.186	.142	.097	.056	.034
10	.033	.053	.077	.119	.165	.192	.204	.185	.140	.096	.054	.033
11	.033	.053	.078	.121	.166	.192	.204	.183	.138	.094	.054	.033
12	.033	.054	.079	.123	.167	.193	.204	.182	.137	.093	.053	.032
13	.034	.055	.079	.125	.168	.194	.203	.180	.135	.091	.052	.031
14	.034	.055	.080	.126	.169	.194	.203	.179	.133	.090	.050	.031
15	.035	.056	.081	.127	.170	.195	.204	.178	.132	.089	.050	.030
16	.035	.057	.083	.130	.172	.196	.203	.176	.130	.087	.048	.029
17	.036	.058	.084	.131	.173	.196	.203	.175	.129	.086	.046	.030
18	.037	.059	.084	.133	.173	.197	.203	.174	.127	.085	.047	.030
19	.037	.059	.085	.135	.175	.197	.202	.172	.125	.082	.045	.030
20	.038	.060	.087	.137	.174	.198	.202	.171	.123	.082	.044	.030
21	.040	.061	.089	.138	.176	.198	.201	.169	.122	.080	.045	.029
22	.040	.061	.090	.140	.178	.199	.201	.168	.121	.078	.043	.029
23	.040	.061	.092	.141	.178	.199	.200	.166	.120	.079	.042	.029
24	.042	.063	.094	.144	.179	.200	.200	.165	.117	.077	.042	.028
25	.042	.064	.095	.144	.180	.200	.200	.164	.116	.076	.040	.028
26	.042	.064	.095	.146	.181	.200	.200	.162	.115	.074	.040	.029
27	.043	.065	.096	.148	.181	.201	.199	.160	.114	.073	.040	.027
28	.044	.066	.098	.148	.183	.202	.198	.158	.112	.072	.038	.028
29	.044	.067	.099	.151	.183	.202	.197	.156	.110	.070	.038	.028
30	.045	.068	.101	.152	.184	.202	.196	.155	.109	.068	.037	.028
31	.045	.068	.103	.153	.186	.202	.195	.154	.107	.067	.036	.028
AVERAGE	1.773	2.357	3.077	4.122	5.593	6.136	6.587	5.768	4.212	2.984	1.676	1.112

TABLE B27.--DAILY POTENTIAL EVAPOTRANSPIRATION, VAN BAVEL.

COMPUTED FROM SOLAR RADIATION USING MEADOW ALBEDO. USE DAILY
VALUES OF AIR AND SURF PLANT TEMPERATURES, WIND SPEED, AND RADIATION.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
01	.062	.087	.121	.170	.221	.241	.254	.241	.198	.161	.122	.081
02	.062	.087	.123	.170	.223	.240	.253	.244	.196	.159	.121	.078
03	.064	.089	.123	.171	.225	.241	.254	.243	.196	.160	.119	.077
04	.063	.090	.125	.172	.226	.242	.255	.242	.195	.158	.118	.077
05	.065	.090	.125	.176	.228	.241	.255	.240	.193	.158	.116	.077
06	.065	.091	.125	.177	.228	.242	.256	.239	.193	.157	.113	.076
07	.064	.093	.127	.181	.229	.242	.254	.238	.190	.155	.112	.074
08	.066	.095	.129	.185	.229	.244	.255	.237	.188	.154	.110	.075
09	.066	.094	.130	.186	.230	.244	.255	.236	.188	.153	.108	.073
10	.068	.096	.133	.187	.232	.244	.256	.234	.186	.152	.105	.070
11	.068	.097	.133	.190	.231	.244	.256	.232	.184	.150	.106	.070
12	.069	.099	.135	.191	.231	.245	.255	.230	.183	.149	.103	.068
13	.069	.100	.133	.193	.233	.245	.255	.229	.181	.147	.102	.067
14	.069	.100	.135	.195	.234	.245	.255	.227	.179	.147	.100	.066
15	.071	.100	.137	.196	.234	.246	.255	.226	.179	.146	.098	.066
16	.072	.103	.139	.199	.235	.246	.255	.224	.178	.145	.097	.063
17	.074	.103	.140	.200	.236	.247	.254	.223	.177	.144	.093	.064
18	.074	.107	.140	.203	.236	.247	.255	.221	.175	.143	.094	.064
19	.075	.106	.142	.204	.237	.248	.254	.220	.173	.140	.093	.064
20	.077	.106	.143	.208	.234	.249	.253	.218	.172	.140	.091	.064
21	.078	.108	.147	.207	.237	.249	.253	.216	.171	.138	.092	.062
22	.079	.108	.148	.210	.238	.249	.252	.214	.170	.136	.089	.062
23	.079	.109	.150	.211	.237	.249	.252	.212	.169	.137	.087	.063
24	.082	.111	.153	.215	.238	.250	.251	.212	.167	.135	.087	.062
25	.082	.113	.155	.215	.238	.250	.251	.210	.166	.134	.084	.062
26	.082	.114	.154	.217	.240	.250	.252	.208	.165	.131	.084	.062
27	.082	.116	.157	.218	.239	.251	.251	.206	.165	.130	.084	.060
28	.084	.116	.158	.219	.240	.253	.250	.204	.164	.129	.081	.060
29	.085	.119	.160	.221	.240	.252	.249	.202	.162	.127	.079	.061
30	.086	.	.163	.221	.240	.253	.248	.200	.161	.125	.080	.062
31	.086	.	.165	.	.241	.	.246	.200	.	.124	.	.062
AVERAGE	2.360	2.987	4.336	5.891	7.226	7.379	7.835	6.916	5.352	4.457	2.957	2.136

TABLE B28.--MEAN DAILY COMPUTED LAKE EVAPORATION.

COMPUTED BY U.S. WEATHER BUREAU FORMULA USING SMOOTHED AVERAGE DAILY
VALUES OF AIR AND DEW POINT TEMPERATURES, WIND SPEED, AND RADIATION.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.018	.025	.039	.072	.120	.159	.176	.166	.126	.084	.046	.022
2	.017	.026	.040	.073	.122	.160	.176	.165	.125	.083	.045	.021
3	.018	.026	.040	.075	.124	.161	.176	.164	.123	.081	.044	.021
4	.018	.027	.041	.076	.125	.162	.176	.163	.122	.080	.043	.021
5	.018	.027	.041	.078	.127	.162	.176	.162	.121	.079	.042	.020
6	.019	.027	.042	.079	.128	.163	.177	.161	.120	.078	.041	.020
7	.018	.027	.043	.081	.130	.163	.176	.160	.117	.076	.040	.019
8	.019	.028	.044	.083	.131	.165	.176	.159	.116	.075	.039	.019
9	.019	.028	.045	.084	.133	.165	.177	.158	.115	.073	.038	.019
10	.019	.029	.046	.086	.134	.166	.177	.157	.113	.072	.037	.019
11	.019	.029	.046	.087	.135	.167	.176	.155	.112	.071	.036	.018
12	.020	.030	.048	.089	.137	.167	.176	.154	.111	.070	.035	.018
13	.020	.030	.048	.091	.138	.168	.176	.153	.109	.068	.035	.018
14	.020	.030	.049	.093	.139	.169	.176	.152	.107	.067	.034	.018
15	.020	.031	.050	.094	.141	.169	.176	.151	.106	.066	.033	.018
16	.021	.031	.052	.096	.142	.170	.175	.149	.105	.064	.032	.017
17	.021	.032	.052	.097	.143	.170	.175	.148	.103	.063	.031	.017
18	.021	.032	.054	.099	.144	.171	.175	.146	.102	.062	.030	.017
19	.021	.032	.055	.101	.146	.171	.174	.145	.100	.061	.030	.017
20	.022	.033	.056	.103	.147	.172	.174	.144	.099	.060	.029	.017
21	.022	.034	.057	.104	.148	.172	.173	.142	.098	.058	.028	.017
22	.022	.034	.058	.106	.149	.173	.173	.141	.096	.057	.027	.017
23	.022	.034	.060	.107	.150	.173	.172	.139	.095	.056	.027	.017
24	.023	.035	.061	.110	.151	.174	.172	.138	.093	.055	.026	.017
25	.023	.036	.062	.111	.152	.174	.171	.137	.092	.054	.025	.017
26	.024	.036	.063	.113	.153	.174	.171	.135	.091	.053	.025	.017
27	.024	.037	.065	.114	.154	.175	.170	.134	.089	.051	.024	.017
28	.024	.037	.066	.116	.155	.175	.169	.132	.088	.050	.024	.017
29	.024	.038	.067	.118	.156	.175	.168	.131	.086	.046	.023	.017
30	.025		.069	.119	.157	.176	.168	.129	.085	.048	.022	.017
31	.025		.070		.158		.166	.128		.047		.017
AVERAGE		.901		2.855		5.061		4.598		2.008		.563
	.646		1.629		4.369		5.389		3.165		.991	

TABLE B29.--MEAN DAILY COMPUTED PAN EVAPORATION.

COMPUTED BY U.S. WEATHER BUREAU FORMULA USING SMOOTHED AVERAGE DAILY
VALUES OF AIR AND DEW POINT TEMPERATURES, WIND SPEED, AND RADIATION.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.031	.040	.055	.097	.156	.199	.223	.217	.168	.120	.075	.039
2	.031	.041	.056	.098	.158	.199	.223	.216	.166	.118	.073	.038
3	.032	.041	.057	.100	.160	.201	.224	.215	.164	.117	.071	.037
4	.032	.042	.057	.102	.162	.202	.225	.215	.163	.115	.070	.037
5	.032	.042	.058	.104	.164	.202	.225	.213	.160	.114	.069	.036
6	.032	.042	.059	.106	.165	.203	.226	.212	.159	.113	.067	.035
7	.032	.043	.060	.108	.167	.204	.226	.211	.157	.111	.066	.034
8	.032	.043	.061	.110	.168	.206	.225	.209	.155	.109	.065	.035
9	.033	.044	.062	.112	.170	.206	.226	.208	.154	.108	.063	.034
10	.033	.044	.063	.114	.172	.207	.227	.206	.152	.107	.062	.033
11	.033	.044	.064	.116	.173	.208	.227	.205	.150	.105	.061	.033
12	.033	.045	.066	.118	.174	.209	.226	.203	.149	.104	.059	.033
13	.034	.045	.066	.120	.176	.209	.226	.201	.147	.102	.058	.032
14	.034	.046	.067	.122	.178	.210	.226	.200	.145	.101	.057	.032
15	.034	.046	.069	.124	.179	.211	.227	.199	.144	.099	.055	.031
16	.035	.047	.071	.127	.180	.212	.226	.197	.143	.098	.054	.031
17	.035	.047	.071	.128	.182	.213	.226	.195	.141	.096	.052	.031
18	.036	.048	.073	.131	.183	.214	.227	.193	.139	.095	.052	.031
19	.036	.048	.074	.132	.184	.214	.226	.191	.137	.093	.051	.031
20	.036	.049	.076	.135	.185	.216	.226	.190	.135	.092	.049	.031
21	.037	.049	.077	.137	.186	.216	.226	.188	.134	.090	.048	.030
22	.037	.050	.079	.139	.188	.217	.225	.186	.133	.089	.047	.030
23	.037	.050	.080	.141	.189	.218	.225	.184	.131	.088	.046	.030
24	.038	.051	.082	.144	.190	.219	.224	.183	.130	.086	.045	.030
25	.038	.052	.083	.145	.191	.219	.223	.181	.128	.085	.044	.030
26	.038	.052	.085	.148	.193	.220	.223	.179	.127	.083	.043	.030
27	.039	.053	.087	.149	.193	.221	.222	.177	.125	.082	.042	.030
28	.039	.053	.089	.151	.195	.222	.222	.175	.124	.080	.041	.030
29	.039	.054	.090	.153	.195	.221	.221	.173	.122	.079	.040	.031
30	.040		.092	.155	.196	.222	.220	.171	.121	.077	.039	.031
31	.040		.094		.198		.218	.170		.076		.031
AVERAGE	1.351		3.766		6.340		6.063		3.032		1.007	
	1.008		2.223		5.550		6.962		4.303		1.664	

TABLE B30.--MEAN DAILY LYSIMETER POTENTIAL EVAPOTRANSPIRATION.

DATA ARE FROM 5-TERM HARMONIC CURVE FITTED TO AVERAGE OF 1948-65 DATA
LESS 1956, 1957, 1964, AND PERIODS WHEN HAY CUT RESTRICTED PET ESTIMATE.

INCHES

DAY	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEP.	OCT.	NOV.	DEC.
1	.020	.027	.046	.068	.154	.222	.222	.213	.160	.109	.052	.020
2	.020	.028	.046	.069	.157	.222	.222	.212	.158	.107	.050	.020
3	.020	.028	.047	.071	.161	.223	.222	.211	.156	.106	.049	.020
4	.020	.029	.047	.073	.164	.223	.222	.210	.155	.104	.047	.020
5	.020	.030	.048	.075	.167	.224	.222	.209	.153	.102	.045	.020
6	.020	.030	.048	.077	.170	.224	.222	.207	.151	.101	.044	.020
7	.020	.031	.048	.079	.174	.224	.222	.206	.149	.099	.042	.019
8	.020	.032	.049	.082	.177	.224	.222	.205	.147	.097	.040	.019
9	.020	.033	.049	.084	.180	.224	.222	.203	.145	.095	.039	.019
10	.020	.033	.049	.086	.183	.224	.222	.202	.143	.094	.037	.019
11	.020	.034	.050	.089	.186	.224	.222	.200	.142	.092	.036	.019
12	.020	.035	.050	.092	.188	.224	.222	.198	.140	.090	.035	.019
13	.020	.036	.051	.094	.191	.224	.222	.197	.138	.088	.033	.019
14	.021	.036	.051	.097	.194	.224	.222	.195	.136	.086	.032	.019
15	.021	.037	.052	.100	.196	.224	.221	.193	.135	.085	.031	.020
16	.021	.038	.052	.103	.198	.224	.221	.192	.133	.083	.030	.020
17	.021	.038	.052	.106	.201	.224	.221	.190	.131	.081	.029	.020
18	.021	.039	.053	.109	.203	.224	.221	.188	.130	.079	.028	.020
19	.021	.040	.054	.113	.205	.224	.221	.186	.128	.077	.027	.020
20	.022	.041	.054	.116	.207	.223	.220	.184	.126	.075	.026	.020
21	.022	.041	.055	.119	.209	.223	.220	.182	.125	.073	.025	.020
22	.022	.042	.056	.123	.210	.223	.220	.180	.123	.071	.025	.020
23	.023	.042	.057	.126	.212	.223	.219	.178	.122	.069	.024	.020
24	.023	.043	.058	.129	.214	.223	.220	.176	.120	.067	.023	.020
25	.023	.043	.058	.133	.215	.223	.218	.174	.119	.065	.023	.020
26	.024	.044	.060	.136	.216	.223	.218	.172	.117	.063	.022	.020
27	.024	.045	.061	.140	.217	.223	.217	.170	.115	.061	.022	.020
28	.025	.045	.062	.144	.218	.222	.216	.168	.114	.060	.021	.020
29	.025	.045	.063	.147	.219	.222	.216	.166	.112	.058	.021	.020
30	.026		.065	.150	.220	.222	.215	.164	.111	.056	.021	.020
31	.027		.066		.221		.214	.162		.054		.020
AVERAGE		1.065		3.130		6.700		5.893		2.547		.612
	.672		1.657		6.027		6.825		4.034		.979	

